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INFORMATION

FOR

AIR SERVICE MECHANICS

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The following publication, entitled "Information for Air Service Mechanics," is published for the information and guidance of all concerned.

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BY ORDER OF THE SECRETARY OF WAR:

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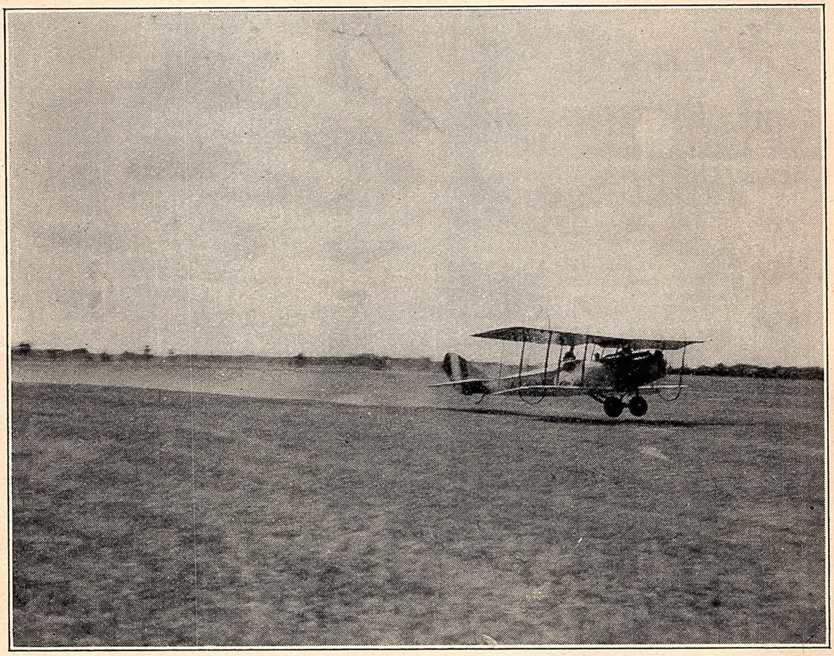
CONTENTS.

Frontispiece.



Taking off.

CHAPTER I.

THE AVIATION MECHANIC AND HIS WORK.

THE IMPORTANCE OF GOOD RIGGING.

It is impossible to exaggerate the importance of *care* and *accuracy* in rigging. The pilot's life, the speed and climb of the airplane, its control and general efficiency in flight, and its duration as a useful machine all depend upon the rigger. Consider that while the engine may fail the pilot may still guide safely to earth; *but* if the airplane fails, then all is lost. The responsibility of the rigger is, therefore, very great, and he should strive to become a sound and reliable expert on all matters relating to his art—for an art it is, and one bound to become increasingly important as time passes.

PERFECTION THE ONLY STANDARD.

Perfection must be the only standard for the aviation mechanic's work. It must not be nearly, or about right, but *exactly* right. The best rigger is the man who has a thoughtful, analytical mind, and who will, from a given effect or trouble, reason out its cause and conscientiously correct it. He will give to the assembly and alignment that serious attention of mind which will produce perfect work, realizing that the airplane itself, the secrets embodied in its design, the money spent by his country in training the pilot, the very life of the pilot himself and perhaps the lives of others as well, all depend upon his work for their safety.

OUTLINE OF RIGGER'S WORK.

It is easy to leave a clear mental picture of the airplane in the student's mind when it is shown that every part of the machine is essential, and is put in its place for a definite purpose. As the student rigger begins to learn his work, and as he begins to see the airplane less as a confused mass of queer parts and more as a logical structure built in accordance with exact principles, it helps him greatly to know that all his work is capable of positive proof.

WORK CAPABLE OF EXACT PROOF.

Point out to him that there need be no uncertainty about his work. Engine troubles may puzzle the motor mechanic, but the cause of any trouble encountered in aligning the airplane may be figured out according to mathematics and readily removed. The airplane is designed and constructed in accordance with the unvarying laws of mathematics. Every step in the alignment can be proven by exact measurements. If the student does each step in his work correctly, and follows his instructions closely, he can not fail to get the right results. The rigger should be taught not to be afraid of his level and steel tape, but to depend upon them. By practice and proof, he must develop such confidence that he can turn over the airplane to his pilot correctly assembled and aligned, knowing with absolute certainty that it is ready for taking the air.

CHAPTER II.

SIMPLE PRINCIPLES OF FLIGHT.

FLIGHT.

First of all the student rigger must have a sound idea of flight and stability and must understand the simple principles of flight.

Flight is secured by driving through the air a surface or surfaces inclined to the direction of motion. Such inclination is called "the angle of incidence," and will be discussed fully later in the manual.

THE AIRPLANE IN FLIGHT.

The airplane is the answer to the question "How can a load be lifted from the ground, transported through the air, and brought back safely to earth again?"

An airplane is a machine consisting of a rigid body or fuselage in which is mounted a gasoline engine, driving a propeller or airscrew, rigid airfoils or wing surfaces (usually four in number), vertical and horizontal stabilizing and controlling surfaces, and a landing gear having wheels. In the fuselage are seats (cockpits) for the pilot and passenger, levers for the controls and gasoline and oil tanks.

THE SLIP STREAM.

The natural function of the engine is to rotate the airscrew. The airscrew, when rotated, causes a stream of air, usually termed the "slip stream" to be driven off behind it and from this is derived a reaction of forward thrust on the blades of the propeller which tends to give the whole machine a velocity forward.

THE KITE.

In flying a kite, as long as the wind blows against it and the string holds it at the proper inclination, the kite will fly. A kite is supported by the air in the same way as an airplane. The kite is held stationary and the air blows against it, but the effect produced is exactly the same as if the kite moved to meet the air and

the air remained still. The airplane designer simply takes large curved panels, holds them rigidly at an upward inclination corresponding to the slant of the kite and pulls them forward through the air at tremendous speed. This is accomplished by means of the motor-driven airscrew which screws its way forward into the air, pulling or pushing the airplane with it.

LIFT AND DRIFT.

When a surface like the wing panel is driven through the air horizontally, the front or entering edge raised a little higher than the rear or trailing edge so that the under side strikes the air as it advances, the air will exert a pressure on the under side at right angles to the surface. This pressure really consists of two parts, the first, a vertical pressure pushing the panel upward called " lift "; the second,

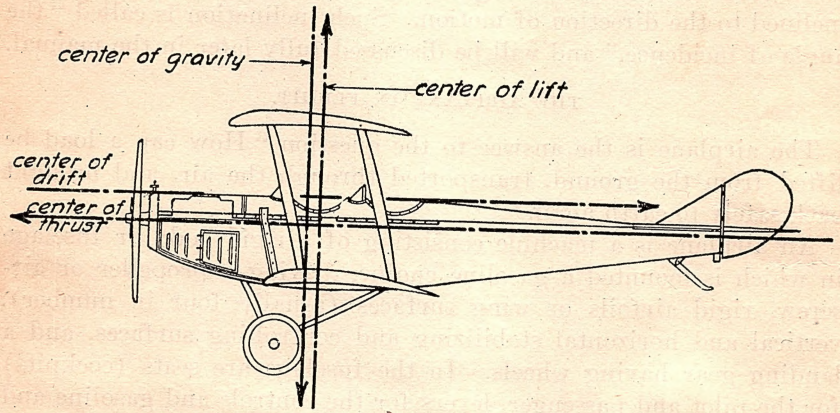


FIG. 1.—Diagram showing lift, drift, gravity, and thrust.

a horizontal pressure pushing the panel backward, called " drift." If the entering edge is raised only a little above the trailing edge, the air pressure will act almost vertically upward so that the lift will be much greater than the drift. In fact, for every pound of drift present there will be 10 pounds of lift.

It will be seen by the diagram above that there are four forces to consider. The lift which is opposed to the weight, and the thrust which is opposed to the drift. This is explained in detail under " Drift."

RAREFIED AREA.

Air has weight, inertia, and momentum. It therefore obeys Newton's laws and resists movement. This resistance and the resisting reaction makes flight possible. The action of the air currents is similar to that of currents of water. As the panel rushes forward, the

air striking its loading edge sprays, or is deflected, upward over it just as a stream rushes outward over the edges of a waterfall. This creates a rarefied area above the panel, and the air in this place has less density than it has under it. Meanwhile, the air passing under the panel is pushing upward against it, and as the panel curves downward toward the trailing edge this curvature prolongs the upward pressure until the air has passed completely across the panel, while at the same time it increases the extent of the rarefied area above the panel.

WHAT LIFT DEPENDS ON.

This action and the resulting lift is continuous as long as the propeller is rotating at speed. Lift depends on—

(*a*) Area.
(*b*) Density of air.
(*c*) Angle of incidence.
(*d*) Speed of motion.
(*e*) Shape of wing curve.

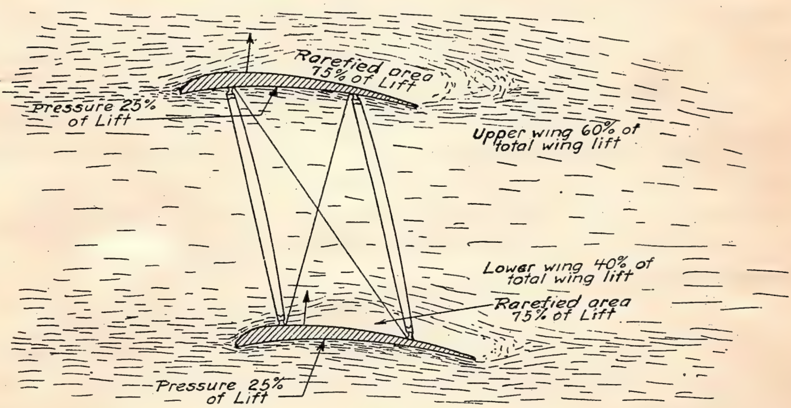


FIG. 2.—Rarefied area.

If 1 square foot of wing surface will give 5 pounds of lift, 5 square feet will give 25 pounds of lift and so on. The weight to be lifted and the speed to be attained will determine the wing area. The heavier or more dense the air is, the more upward pressure or lift it will furnish to the wing pushing it down. The air is heaviest or more dense near the ground, its density at 20,000 feet up being only half of what it is at ground level. Therefore a wing gets more lift at a low altitude than at a high altitude. When the angle formed by the panel with the wind is smaller, the lift is smaller. The lift of the panels, however, increases with an increase in the angle at which they are inclined only up to a certain point. Beyond that point, an in-

crease in this angle will not increase lift. This point is called the "stalling point" or the "stalling angle." If the wing panel is held in a fixed position at a given angle of incidence, an increase in the speed of the airplane will result in increased lift, and, should this speed rise from 40 miles per hour to double this amount, the lift will increase still more, in fact to about four times as much. Lift varies as the square of the speed.

DRIFT.

Now, roughly speaking, we find that there are four forces acting upon an airplane in flight as shown in the diagram. First the attraction of gravity will exert a continuous pulling downward force upon the weight of the airplane. This must be equaled by the second force, lift, to maintain a condition of steady flight. And when lift exceeds the pull of gravity the airplane will rise. Lift will not come, however, until the wing panels move forward through the air, and they will not do this until the force "drift" or the horizontal reaction of the air upon the airplane surfaces has been equaled by the forward pull or thrust of the propeller.

The amount of drift to be equaled is the measure of the force which must be supplied by the engine to the airscrew. In steady, horizontal flight at any given speed, the propelling forces exactly equal the resisting forces; but when the airplane is to ascend, the propelling forces must be more than equal—they must overcome the resisting forces.

As more drift directly necessitates more power, consequently a larger and heavier engine and more fuel, thus using up lift, let us consider how to reduce drift.

KINDS OF DRIFT.

The drift of the whole airplane may be conveniently divided into three parts, as follows:

Active drift is the drift produced by the lifting surfaces and refers to the wind or forces actively retarding the airplane's advance. We have no control over this force.

Passive drift, or head resistance, is the drift produced by all the rest of the airplane—the struts, wires, fuselage, undercarriage, and similar exposed surfaces in their passage through the air. It is generally considered to be not so much the resistance offered to the leading edges as it is the backward pull coming from the air eddies created behind the trailing edge. This can be reduced by streamlining parts wherever possible.

Skin friction is the drift produced by the friction of the air with roughnesses of surface, such as muddy or torn wings. This we can

reduce by painting and varnishing the wing panels to a glasslike smoothness, varnishing the struts and fuselage and keeping the surface of the airplane clean and free from mud.

STREAMLINING.

A streamline shape is one in which the thickest part is in front and tapers to a point in the rear, providing smooth lines of flow for the air, which has been thrust at the front to flow back without eddies to the rear. By making struts, wires, and panels conform to this shape and by streamlining the fuselage itself, drift can be greatly reduced, thereby increasing the lift and speed. In fact, for every pound of drift eliminated we gain 10 pounds of lift. A streamlined object is generally three times as long as it is thick or wide and the point of its greatest thickness is one-third of the distance back from the leading edge. The fuselage, which offers the lowest drift per square foot of cross sectional area, is a torpedo shape of length equal to about five times its greatest diameter. A

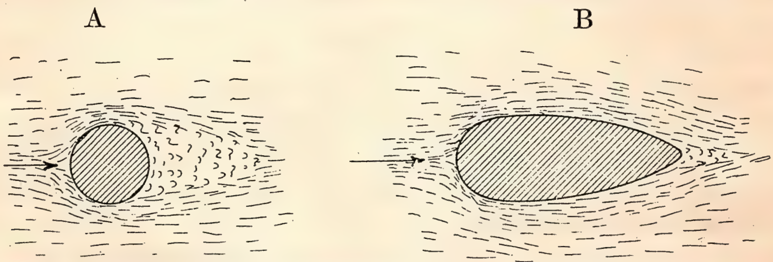


FIG. 3.—Diagram showing air flowing against a sphere (View A), and against a streamlined shape (View B).

68 miles per hour

body of this form may have as low a drift as 1 pound per square foot of cross-sectional area at a speed of 100 feet per second. Substituting streamlined wires for those of a normal shape on an airplane has increased its speed 5 miles per hour.

LIFT-DRIFT RATIO.

The proportion of lift to drift is known as the lift-drift ratio. This is of paramount importance, for upon it depends the efficiency of the airplane. The vertical force, lift, acting on the wing panels, supports the whole weight of the airplane. The horizontal pressure, drift, or the air's resistance to the airplane's passage through it, must be overcome by the force supplied to the panels.

CHANGES IN LIFT.

The curved wing sweeps the air down smoothly and without undue disturbance of the air currents, therefore the shape of the wing curve is most important, and of the two curved surfaces of the panel the

upper one deserves the most attention for it is from this surface that about 75 per cent of the total lift supplied by the panel is derived. By wind-tunnel experiments the most efficient wing curve for an airplane of a certain type designed to fly within certain limits of speed is determined. Due to this curve, the panel retains its lift until the angle of incidence at which it is set is minus $2\frac{1}{2}°$. At this point there would be no lift. From that point again, as the angle of incidence is increased, the lift will increase until that angle is plus 15°, and beyond this point it decreases. So between $2\frac{1}{2}°$ and plus 15° is the total range of useful attitude of an airplane wing. In practice the drift is less in proportion to the lift secured when panel is set at a low angle of incidence than at a high angle of incidence, and the lift-drift ratio is usually best when the angle of incidence of the panel is about $3\frac{1}{2}°$. The center of lift refers to that point on the panel where the center of lift occurs. The center of lift comes from 35 to 36 per cent, or about one-third of the chord length back from the leading edge of the panel at ordinary angle of attack. At large angles it moves up near the front spar; at small angles it moves back near the rear spar.

ASPECT RATIO.

The "aspect" of an airplane is always considered as its total span divided by the chord of the wings, the wings not being considered separately from their attachment to the body. Therefore the aspect ratio refers to the ratio of the span or length of an air foil to its chord or width, and, speaking broadly, the higher the aspect ratio the greater will be the maximum lift per square foot. This is because the long, narrow wing engages more undisturbed air than does the wing that is short and broad. Consequently, weight-lifting airplanes, such as bombers, battle planes, and training machines, have wings of high-aspect ratio, while light, swift, single-seated fighters have short, broad wings of low-aspect ratio. The amount of wing-tip spillage is theoretically less with the wing of high-aspect ratio, as there is less width of wing tip over which the air currents can slip off sideways before they have contributed their fair proportion of lift than there is with the wing of low-aspect ratio. For wings set at a small angle of incidence, an aspect ratio of about 7 to 1 is good.

RAKEBACK.

Rounding off the end of a wing panel somewhat increases the efficiency as a turbulent or eddying air current is set at a sharp corner, and power is wasted in so doing.

STABILITY AND CONTROL.

Next to be considered are the stabilizing and controlling surfaces of the airplane. First remember that the airplane is a machine en-

tirely immersed in air, and that its average weight per cubic foot is so much greater than that of the surrounding atmosphere that it is in no wise supported by displacement, as is the balloon. Furthermore, an airplane depends entirely for its support and direction upon its speed relative to the air. Consequently, if the airplane is to have stability or steadiness—meaning by this a tendency of its own, first, to resist any external force acting to throw it out of its normal position in flight, and, second, to return more or less quickly to that position as soon as that force ceases—we must balance against each other the forces operating upon it in normal flight.

FORCES ACTING ON AIRPLANE.

Of the four forces before mentioned, two are vertical forces—lift (a total of the lift of panels, tail, and body) pushing upward and the weight pulling downward. Two are horizontal forces—the drift pushing backward and the air-screw thrust pulling forward. These forces must be balanced so that the total lift is equal to the weight and the thrust equal to drift. However, lift must overcome weight and thrust must overcome drift if the airplane is to fly forward. The center of gravity or weight is the natural point at which to start, and if it is back at the tail or up at the nose there will be no balance. The proper place for it is at the point where the other forces (lift, drift, and thrust) act and where it will be easier to balance them all.

CENTERS OF GRAVITY AND LIFT.

It is desired to have the center of gravity ahead of the center of lift, so that when the power is cut off, removing the influence of three forces on the airplane (thrust, lift, and drift), the effect of the only force still operating on the airplane—that of weight—will be a helpful one, causing the airplane to nose down and, assuming the proper gliding angle, come safely to earth. Naturally, if the center of gravity and the center of lift were both at the same point, this would not happen, and when the power was cut off the machine would pancake or fall flat to the ground. Therefore, when the center of gravity is moved ahead of the center of lift, the designer deliberately locates his center of thrust sufficiently far below the center of drift, so that in flight it counteracts the tendency of the airplane to nose down, and all four forces completely balance each other, thus securing stability.

KINDS OF STABILITY.

The airplane must have longitudinal, directional, and lateral stability.

LONGITUDINAL STABILITY.

By longitudinal stability is meant the fore and aft balance. In other words, it refers to the stability of the airplane in the direction of its length and tends to keep it from "pitching" or trying to fly nose down or tail down.

DIRECTIONAL STABILITY.

By directional stability is meant the natural tendency of the airplane to remain head-on in its course, and prevents it from "yawing" or turning to the right or left. Directional or "weather cock" stability is secured by having all the parts of the airplane which contribute to its total keel surface of the proper size and in the right position. By keel surface we mean everything seen when you look at the airplane from the side, including the struts, side of fuselage, landing gear, tips of wings, etc. If the airplane is to promptly resume its original direction after being momentarily diverted from it by a side gust of wind, there must be more of this keel surface behind than in front of its vertical axis. Then, too, there must be an equal amount of this keel surface on each side of the longitudinal axis of the airplane, otherwise it will roll from side to side. The size and position of the fin or vertical stabilizer finally decides the directional stability of the airplane. This flat triangular panel is fixed on top of the horizontal stabilizer at right angles to it, and is edge-on to the air stream when the airplane is in normal flight. The slightest deviation from the straight course of the airplane causes the force of the air stream to be felt on the side of the fin and this force, acting at the end of the long lever arm formed by the tail section, is sufficient to swing the nose of the airplane head-on to the wind once more.

HOW CENTER OF LIFT MOVES.

The first thing to remember in considering longitudinal stability is that while the center of gravity and other forces remain in a fixed position the center of lift changes its position whenever the angle of incidence of the panels is changed. For instance, consider an airplane balanced in a normal condition of flight and moving steadily along. Suppose a momentary gust of wind of considerable force strikes the airplane, forcing its nose down. The center of lift moves backward across the panel and unless some other force were supplied to bring it back into normal position again the pull of gravity might easily overbalance lift and bring the machine into a nose dive.

THE HORIZONTAL STABILIZER.

So a large panel, generally of semicircular shape, known as the horizontal stabilizer, is fastened flat on the top longerons

at the tail in such a way that it meets the wind at a smaller angle of incidence than do the wings. Now, when the downward push on the nose sends the tail up, a restoring force is at once supplied through the resistance of the air to the stabilizer's upward movement, and this force, while small in itself, acts at the end of such a long lever arm that it is sufficient to push the tail down and restore a condition of equilibrium. In precisely the same way, the reaction on the stabilizer acts to lift the tail up when it is pushed down and the nose is raised. So longitudinal stability for an airplane is a question of a large enough stabilizer, set at what

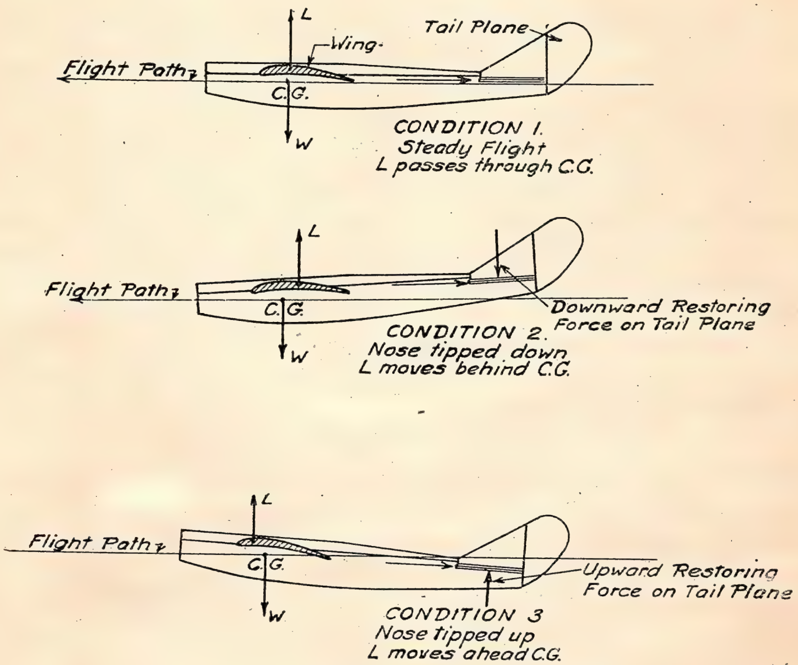


FIG. 4.—Diagram showing longitudinal stability.

is termed a longitudinal dihedral angle to the wing panels. Naturally, as the stabilizer acts in the slip stream, driven off by the airscrew, it will be fully efficient only when the airplane is flying at a good speed.

POSITION OF HORIZONTAL STABILIZER.

It should be noted that the stabilizer acts in the wash of the wing panels and this air wash has a downward slant toward the tail. This must be considered in determining the size and setting of the stabilizer. As the stabilizer must set both upward and downward

in maintaining stability and with equal effect in either direction, it is set in modern airplanes in what is called "neutral position," meaning by this that it is edge-on to its relative motion through the air. As the air through which the panels have passed receives a downward motion, it would pass this on to the tail in the shape of an actual downward push on the stabilizer, unless it were given, as is the practice, a slight upward curve on its top surface. This is because such a curved surface has an angle of zero lift, which is a negative angle.

LATERAL STABILITY.

By lateral stability is meant the sideways balance of the machine. This keeps the airplane steady across its span and prevents its "rolling" or "banking" in the air. When one wing of an airplane is tipped downward the center of lift is thrown to one side and out of line with the center of gravity. So the resulting influence of lift and gravity then causes the airplane to move sideways and downward. Now, if the wing panels are given a slight upward inclination from the center out, the lift on the lower wing when the airplane is tipped sideways will increase, while the lift on the upper wing, as it moves farther away from the horizontal or most efficient position, will decrease. Thus, the wing on the downside will come up and the airplane once more will resume its normal position.

LATERAL CONTROL.

Lateral control is attained by double acting ailerons or wing flaps. If the airplane tends to side slip when making a turn, the pilot moves his joystick or wheel, pulling the aileron on the low side down and the aileron on the high side up. This action is equivalent to increasing the camber and angle of incidence of the low wing, increasing it so that it gets more lift than the high wing on which the opposite action takes place, its angle of incidence and consequent lift decreasing. The low wing comes up, the high wing comes down, and the airplane assumes its normal position.

CHAPTER III.

FUNDAMENTALS OF FIELD RIGGING.

CARE OF TOOLS.

The best workman is known by the excellent condition in which his tools are kept, his smooth and systematic performance of work, and his economical use of material. The aviation mechanic should exemplify these qualities in his work, for upon careful execution of its every detail human life depends, and in it he uses expensive tools and materials.

CORRECT HABITS OF WORK.

The rigger must form correct habits of work. He must keep his tools in good condition, clean, and well oiled. He must inspect his material carefully, use it economically, and handle it so as to avoid injury to it. If the outside fibers of a strut are broken, for instance, its strength is impaired, and if a wire is kinked, it may break and by so doing cause the loss of the entire plane.

PROPER TOOLS IMPORTANT.

A great thing to remember is that the airplane can be assembled from its component parts and aligned quickly and accurately if the proper tools are correctly used and the work is done systematically. Brute force must never be used in putting together its expensive, delicate, and correctly designed parts. The mechanic must think and observe. Every tool is made for a certain kind of work, so do not use it for any other purpose. Never use pliers on turnbuckle barrels, bolts, or screws. They disfigure and weaken them. Pliers are made for use in wirework only. Use end and socket wrenches only when of the proper size for nuts. Care must be taken with adjustable wrenches to adjust them to fit nuts when in use, as a slip here might cause injury. Do not use a wrench for a hammer. Cotter key extractors are for removing and spreading cotter pins; do not use them for turning turnbuckles or for screw drivers. Never lay tools on the ground but keep them in the kit provided. Lay out all your tools in order before starting work.

BOLTS AND CLEVIS PINS.

Never lay parts of the airplane on the ground or on the airplane but have a box handy to put them in. In active service, it is almost impossible to replace lost parts. Bolts should be kept clean, free from rust and well greased. Bolts must properly fit holes in which they are placed. If the hole is too large, the bolt will work it larger and if too small, the bolt is liable to split the wood. Tap bolts in lightly, using a piece of wood or a drift pin and do not hammer their ends. The general rule for correctly placing bolts and clevis pins is to put them in from the top down, from the front back and from the outside in. Then if the nuts come off the bolts will stay in place, held there by the pull of gravity or the pressure of the air stream. All bolts, clevis pins and hinge pins should be cotter keyed as soon as inserted so none will be overlooked. Never tighten a nut with all your strength. The rule in airplane rigging is to "tighten nuts firmly."

CARE OF WIRES.

Coil up all wires as soon as you unfasten them and don't leave them hanging loose to be walked on or to get covered with grit and dirt. Keep wires in good condition, first wiping them off with a dry rag to remove dirt and then with oily waste to give them a coat of oil or grease which will keep out the rust. In this work when running your hand over the wires, you will quickly detect any frayed wires. Remove such at once and replace with new ones. Be especially careful in your inspection of wires where they pass around pulleys or through fair leads.

TENSION OF WIRES.

Avoid excessive strain on any wire. Each wire is designed to stand up to a certain amount of work. Do not put too much tension on it for by so doing, you lessen its factor of safety and consequently the factor of safety of the entire airplane. Flying wires should be tight enough so that you can pull them down with one finger about one inch where they cross the landing wires. The overhang flying wires may be left a little looser than the inside flying wires. If the cloth covering or "skin" is wrinkled, it shows that some wire is drawn up too tight. The wire will give way or a strut will bow when the airplane is flying. Where two landing or flying wires are rigged together, they should be at the same tension which can be determined by feeling them. One wire is doing all the work if it is tighter than the other.

HOW TO COIL WIRES.

Wires should be neatly coiled as follows: Grasp wire at attached end, not at loose end, and make number of loops necessary to coil hard cable 9 inches in diameter and flexible, or control cable 6 inches in diameter. Slip free end through center of loop once and around wires of loop, and then through center again, which should be sufficient to hold coil in shape. Pass turnbuckle through coil and do not

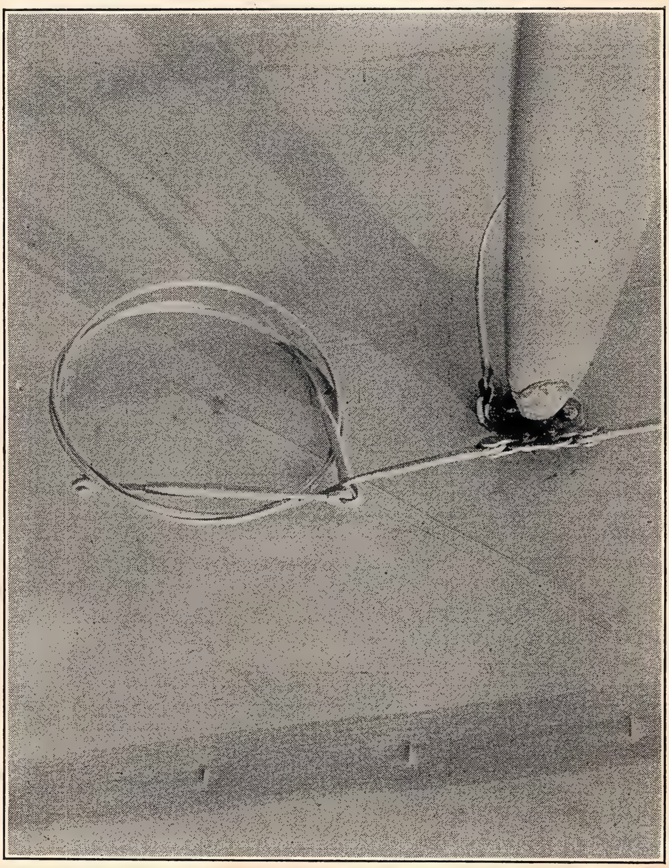


FIG. 5.—Correctly coiled wire.

let it hang loose. This prevents injury to turnbuckle and to nearby panels and holds the coil together. Be careful not to twist turnbuckle too sharply through loop as wire is very likely to kink near the loop if this is done.

HOW TO COTTER NUTS.

Cotter pins should be placed immediately in all bolts and clevis pins in such a manner that nuts on bolts can not turn. Cotter pins

should be snugly bent around clevis pins, their ends cut off so that each end will reach one-quarter way round. In cottering nuts, cotter pins must come between castellations of nut. If hole for cotter pin comes above castellations, use shorter bolt, drill new hole, or temporarily put washer under nut to bring it up. With pliers push the head of cotter pin down into castellation and bend one end snugly up over end of bolt, other end down over nut. Cut cotter pins to proper length with pliers as long pins may tear the fabric or catch in hinges. Never use same cotter pin twice. Replace each nut on the

Fig. 6.—Cotter key correctly placed.

bolt from which it was removed and which it fits. A good sharp pair of side cutters should be used for this work.

HOW TO SAFETY WIRE TURNBUCKLES.

All turnbuckles are to be safety wired as soon as airplane is aligned. Pass wire through hole in barrel of turnbuckle, drawing one-half of wire straight down the turnbuckle barrel to eye at each end. Pass wire through eye, drawing it tight by hand not with pliers as these would kink it over a sharp edge. Then wrap wire around shank of turnbuckle from four to six times at each end, finally tucking end under the wire to hold it. Make your work neat and workmanlike

and see that turnbuckle is locked so as to actually keep it from turning.

HOW TO SAFETY WIRE HINGE PINS.

Take safety wire in middle, pass it once around groove at head of hinge pin, crossing ends of wire on the inside next to the fuselage. Then bring the ends down over the fitting, passing one end down and one end up through hole in end of pin. Then pass ends completely around fitting again but do not wrap around groove or pass through hole in pin. Now the ends are again free at points of hinge pin. Pass ends around fitting again and then pass one end through the hole so that both ends will be on the same side. Now twist them together. Thus there are three complete turns of wire around wing hinge fitting; the first turn passing around groove in head with two ends passing through hole, the second turn passing around fitting only, the third turn passing around fitting and one end passing

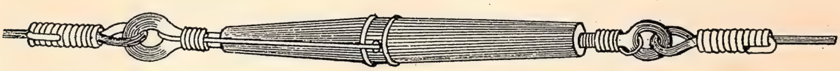


FIG. 7.—Method of wiring turnbuckle.

through hole so that ends can be twisted together. The proper safety of hinge pins is very important in safetying airplanes.

CARE OF TURNBUCKLES.

Keep turnbuckles off the ground; clean them and graphite them so they will work easily. Start both eyebolts in turnbuckle ends at the same time. Never use pliers on turnbuckle, as they will bend or perhaps collapse the barrel. If turnbuckle threads are injured, this will weaken grip of the eyebolt and perhaps cause it to pull out. Use nail or piece of hard wire to turn turnbuckles, holding wire loop with fingers. Never allow a wire to twist when adjusting a turnbuckle.

CARE OF WINGS.

As the wing panels are the agents which directly give the airplane its lift, they must be carefully watched and kept in the best of condition. Do not lift wing panels by means of the trailing edge, but use the hand holds provided for that purpose at the wing butt or use the struts. Place entering edge of panels down when on ground, resting on padding or cushions. Do not lay panels flat on ground or where they can be blown over by wind, but lean them against supports and tie them there. Keep your struts off the ground, so that there is no

possibility of their being walked on or splintered. It is good practice to wire them together through the holes in their ends.

CLEANLINESS ESSENTIAL.

Keep wings clean and free from oil and grease, as such will rot fabric. Mud on the fabric will roughen the surface and produce drift. Warm water and soap without alkali in it is good for washing wings. When mud is found on panels it should be moistened and scraped off, but never scraped off dry.

CHAPTER IV.

PROPERTIES OF THE AIRPLANE.

Too much importance can not be placed upon the necessity of the aviation mechanic understanding the simple principles of flight as explained previously, so that he knows what adjustments to make in correcting certain faults and how to make such adjustments. He must consider and reason things out and understand exactly what he is doing. His work is too important to be based in any degree upon guesswork.

ANGLE OF INCIDENCE.

As stated before, flight is secured by driving forward through the air curved panels which are held rigidly at a certain upward inclination. This inclination, or the angle which the chord of the wing makes with a horizontal line when the airplane is in true flying position, is called the angle of incidence. True flying position means that position in which the airplane is placed for alignment when the engine bed is level laterally and longitudinally. It is generally determined by placing a spirit level on the top longerons, which are in most airplanes parallel to the engine bed. The correct angle of incidence for each airplane, taking into consideration its weight, carrying capacity, speed, climb velocity, etc., is determined by the designer with computations, actual flying, and wind-tunnel experiments. In modern practice, an angle of incidence running between 2 degrees and 4 degrees is generally used. As regards the rigger's work, the angle of incidence refers to the angle at which the panels are rigidly hinged to the fuselage, the position of the hinge fittings on the side of the fuselage fixing this angle. All the rigger has to do with the angle of incidence is to see that this angle of incidence is the same all along the wing right to its tip; in other words, that the wing is aligned correctly and is not warped. The angle of incidence will not be the same on both wings if the fuselage is out of alignment.

MEASURING ANGLE OF INCIDENCE.

Measure the angle of incidence as follows: With the airplane in flying position, place a straightedge against the underside of

lower panel near its butt. With a protractor level measure the angle formed by this straightedge with a horizontal line, this being the angle of incidence. If no protractor is available, then use another straightedge resting against the trailing edge to represent the horizontal line, leveling it up with a spirit level on the straightedge. Measure up from top of this straightedge to the top of the first

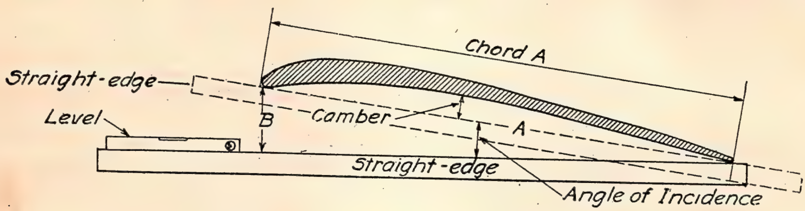


FIG. 8.—Angle of incidence.

straightedge at a point immediately below the panel's leading edge and call this distance "B." Get the distance in inches on the horizontal straightedge from the trailing edge to point from which you measure up to leading edge and call this distance "A." Multiply "A" by 0.0175, the sine of one degree. This will give you the rise in

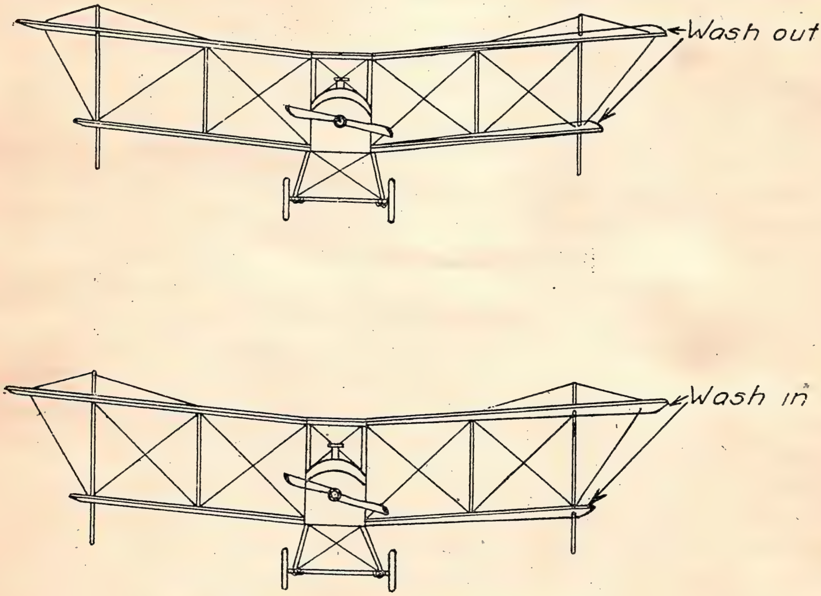


FIG. 9.—Wash-in and wash-out of wings.

inches for an angle of 1 degree in the distance "A." Call this product "C." Now divide "B" by "C." The result will be the number of degrees in the angle of incidence at which the panel is set, and this figure should correspond with the specifications given you. Remember "A" times 0.0175 equals "B" divided by "C," equals number of degrees in angle of incidence.

WASH-IN AND WASH-OUT.

Wash-in or droop refers to an increase of the angle of incidence of the wing toward the wing tip. Wash-out refers to a decrease of the angle of incidence of the wing toward its tip.

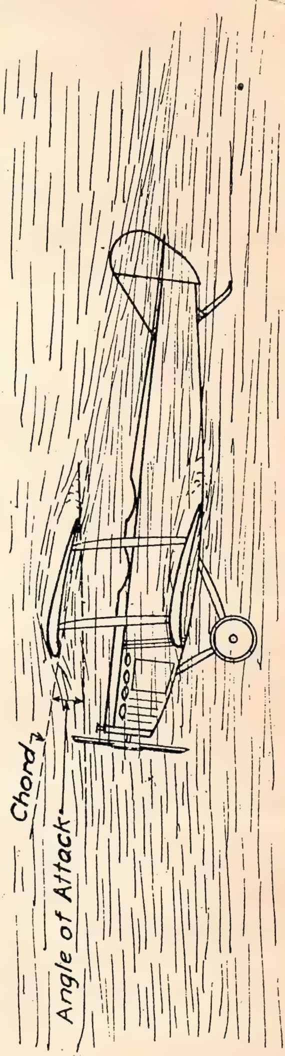


FIG. 10.—Angle of attack.

ANGLE OF ATTACK.

The angle of attack, as far as the rigger is concerned, is the angle formed by the chord of the wing and the line of the relative wind. The relative wind means practically the air stream which the panel attacks. Consequently this angle of attack will change as the airplane ascends or descends. The angle of incidence, however, as regards the rigger's work, does not change, for it is the angle at which the wing panels are attached to the fuselage. These two angles at one particular position may coincide, this position being the true flying position.

DIHEDRAL ANGLE.

For the rigger's work, the dihedral angle is equal to the angle formed by the upward rise of the wings and a line parallel to the entering edge of the center section panel, otherwise a horizontal line. In some airplanes the lower panels only are set at a dihedral angle, but generally both panels are set at a dihedral angle. Its purpose is to help give the airplane lateral stability. The wing panels are set at their most efficient position for forward flight when their leading edges are horizontal. It is calculated that the wings lose 5 per cent of their lift for every additional degree of dihedral angle put in, thus removing them farther from their most efficient position; when the airplane is tilted sideways by a gust of wind, the lower wing is horizontal, or in its most effective position, and its lift is increased, while the upper wing is tilted upward and the upward component of the lift on this wing is less than on the

other. Consequently, the lower wing comes up, the upper wing comes down and the airplane resumes its normal position. The dihedral angle also assists the airplane to assume its correct bank ~~on a turn.~~ In making a turn, too little bank will cause skidding and too much bank will cause side slipping, either being dangerous. The upward inclination of the wings at a dihedral angle causes the airplane to bank against the direction of slip and brings it back into position.

OBJECTIONS TO DIHEDRAL ANGLE.

The setting of the wings at a dihedral angle takes away a certain amount of lift and also causes the airplane to roll in windy weather if it has a large dihedral.

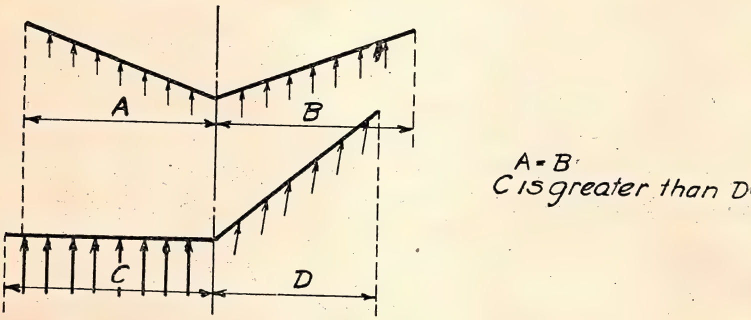


FIG. 11.—Dihedral angle.

THREE WAYS OF CHECKING DIHEDRAL.

There are three ways of checking the dihedral angle after the wings have been brought up to this inclination through the use of the landing wires. First, measure out on the leading edge of each upper panel a certain fixed distance from the butt of the wing, this distance being the same on each side. Mark this point with a small tack driven in the center of the leading edge. Fasten a strong cord or wire to the tack on one panel and hang the loose end over the other tack with a weight attached to pull the line taut. Now calculate the distance in inches which the cord should be above the leading edge when the panels are set at correct dihedral angle by one or two methods, as follows:

(*a*) Number of inches measured out on wing, divided by 57, multiplied by number of degrees of dihedral, equals number of inches between cord and center of panel's leading edge at center section; or

(*b*) Number of inches measured out on panel multiplied by 0.0175 multiplied by number of degrees of dihedral equals rise in inches. (This method can not be used on an airplane having back-swept wings.)

CHECKING DIHEDRAL ANGLE.

Having now the desired measurements in inches, pull up your panels with front landing wires till measurement up from center of center section panel's leading edge on each side to the cord equals this measurement. Allow from one-eighth inch to one-fourth inch additional rise in inches when first putting in dihedral to allow for the change which will be caused by the downward pull of the tensional flying wires. Make a small center punch mark on the center of the lower strut fitting on each wing. Put a small tack in the exact center of the leading edge of center section panel. Hook tape over tack and measure to punch mark on outside struts. These distances should be equal. Similar measurements can be taken to inner lower strut fittings. Check correct location of strut fittings measuring out from butt of each panel to their center points. Such measurements should be equal.

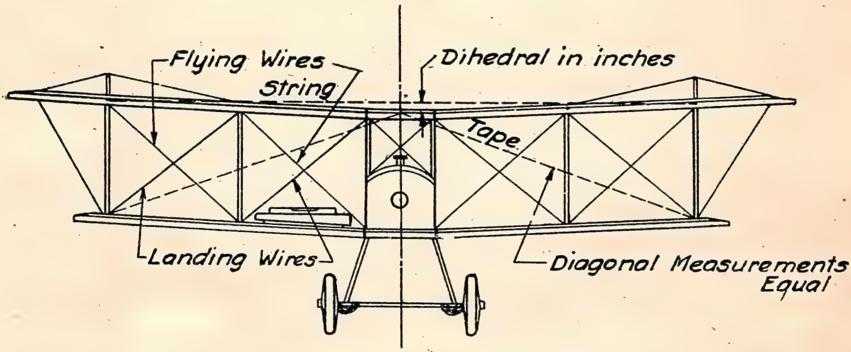


FIG. 12.—Checking dihedral angle.

DIAGONAL MEASUREMENTS USED ALONE.

In aligning a number of airplanes of the same model, these diagonal measurements can first be determined by aligning two or three airplanes correctly, and the correct dihedral angle can then be put in the other airplanes by using the diagonal measurements alone.

DIHEDRAL BOARD.

A straightedge or dihedral board may be used, having lower edge cut at an angle of the required number of degrees with the other edge. Place the lower edge of the board on wing panel, resting spirit level on top edge and bring up panel with landing wires till straightedge is horizontal. To make a dihedral board of the required number of degrees if no protractor level is available, first take the length

of straightedge in inches and calculate the rise in inches for an angle of the required number of degrees in this distance, using 0.0175 as the decimal for 1 degree. Second, measure down on its end from one corner of straightedge a distance equal to this rise in inches. Draw a line connecting this point with the opposite corner of straightedge. Nail a strip of wood along this line and when using the dihedral board thus made, rest spirit level on this strip of wood to determine the correct dihedral. This method is used on airplanes having back-swept wings.

MEASURING LANDING WIRES.

In some cases the airplane manufacturer specifies the length of the landing wires when the wings are set at the correct dihedral angle

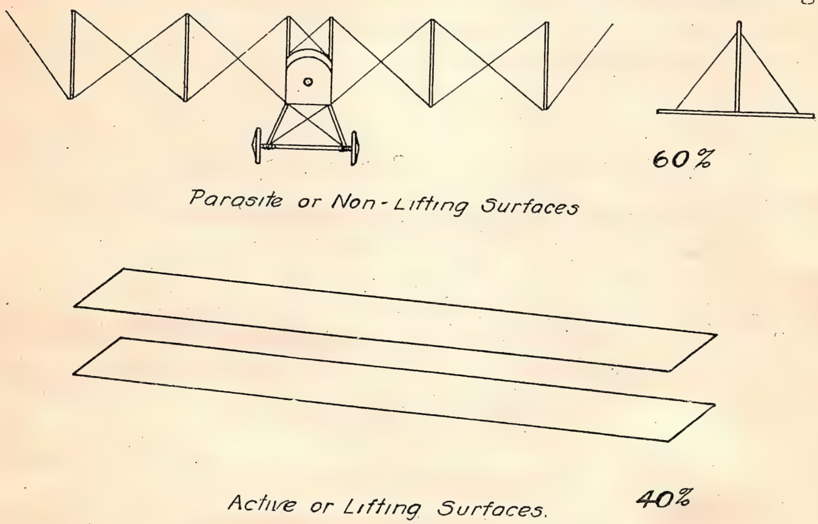


FIG. 13.—Active or lifting surfaces.

and it is only necessary to pull up your panels and check the lengths of these wires.

ALIGNMENT OF CHORD.

The angle of incidence at which the wings are set being specified by the manufacturer, it is the work of the rigger to see that the wing is set at this correct angle of incidence all along its length. This angle is fixed at the butt of the wing by the hinge fittings to which the panel is secured. After the wing has been brought up to the correct dihedral angle along its leading edge by pulling up on the front landing wires, it is only necessary to bring up the trailing edge likewise, so that it is parallel to and in alignment with the leading edge. The angle of incidence will then be correct along the whole

wing. The trailing edge is frequently warped, in which case the rigger should sight the fittings under the lower panel at the trailing edge in aligning the chord, selecting a fixed point on each fitting, such as a nut and not the whole fitting itself, to sight with. If in a poor light, touch up this point on each fitting with a bit of white paint or scrape it so that it shines. In aligning the chord, select a position in front of airplane where the diagonal bracing wires of landing gear form an X to the eyes, and then assume a position from which you can sight under both lower panels.

CHECKING ALIGNMENT OF CHORD.

After aligning the chord, one wing can be checked against the other by making diagonal measurements from top fitting on rear center section strut to point opposite outer rear strut on each lower panel, measuring out to this point from wing butt. This check would naturally be made before droop is put in the wing.

STAGGER.

Stagger refers to the projection of the upper panel forward over the lower one. A very few wings have stagger in the reverse direction. Its purpose is to increase the efficiency of the lift on the panels by permitting each panel to operate in air undisturbed by the other one. It also permits a smaller gap between the panels and consequently shorter struts and wires, and a more compact wing structure.

ADVANTAGE OF STAGGER.

With wide wing panels exactly above each other, the air currents rebounding from the lower panel would strike the upper panel near its trailing edge, thus producing drift instead of lift unless the gap is about one and one-half times the length of the chord. Such a gap necessitates long struts and wires and weakens the wing structure. Ninety per cent lifting efficiency can be secured by staggering the upper panel forward over the lower one, so it will operate in air undisturbed by the lower panel. This is usually done, and the resulting gap is but little longer than the chord. The air currents rebounding from the lower panel then slip off behind the trailing edge of the upper one without interference, and the panels, placed close together, can be strongly braced.

NECESSITY FOR CORRECT STAGGER.

The center of lift is located by the designer at the proper point on the wing panel when the airplane is aligned with the correct amount

of stagger. Consequently, if the airplane is to fly rightly the rigger must see that it has exactly the proper stagger. Otherwise, with too much stagger, the center of lift is brought forward too near the center of gravity so that the weight overbalances the lift, pulling the tail down and making the airplane fly tail heavy. On the other hand, if too little stagger is put in, the center of lift moves back farther away from the center of gravity and weight again overcomes lift, pulling the nose down and making the airplane fly nose heavy.

ADJUSTMENT OF STAGGER.

In adjusting the stagger, the airplane is put in flying position and the plumb lines are dropped over leading edge of upper panel. Then six measurements are taken, three on each wing, with steel rule held horizontally, of the shortest distance between this plumb line and the leading edge of lower panel. Adjustments are made with stagger wires till these measurements correspond to the specified stagger.

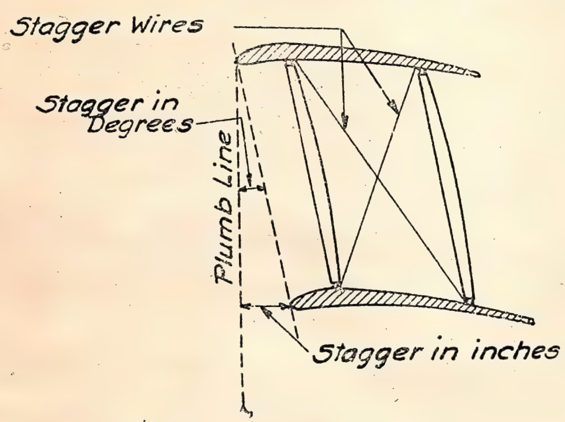


FIG. 14.—Adjustment of stagger.

COMPUTING STAGGER GIVEN IN DEGREES.

With some airplanes, the stagger is specified in degrees. To calculate this measurement in inches, put airplane in flying position, bring stagger wires up till threads on turnbuckles are covered, then with plumb line dropped over leading edge of upper panel, get vertical distance in inches between leading edge of upper panel and point opposite center of leading edge of lower panel. Multiply this by 0.0175 for rise in inches of angle of 1 degree in this distance and this again by number of degrees specified for stagger to get stagger measurement in inches.

TORQUE.

An airplane tends to turn over sideways in the opposite direction to which the propeller revolves. The force of this action is greatest at a point nearest the engine and decreases out toward the tip of the

wing. As this tendency to turn the airplane over will force down the wing on the side opposite the propeller's down stroke, it is counteracted by increasing the angle of incidence of that wing or giving it wash-in. This is done by letting out on the rear landing wires on the wing to be drooped, being careful to keep the rear spar as straight as possible. The amount of droop is determined by the horsepower of the engine and the lifting area of the wings, an airplane like the Curtiss *JN4–B* with 90-horsepower engine taking about a one-fourth inch droop; this refers to the amount by which the trailing edge of the wing is lowered beneath its normal position.

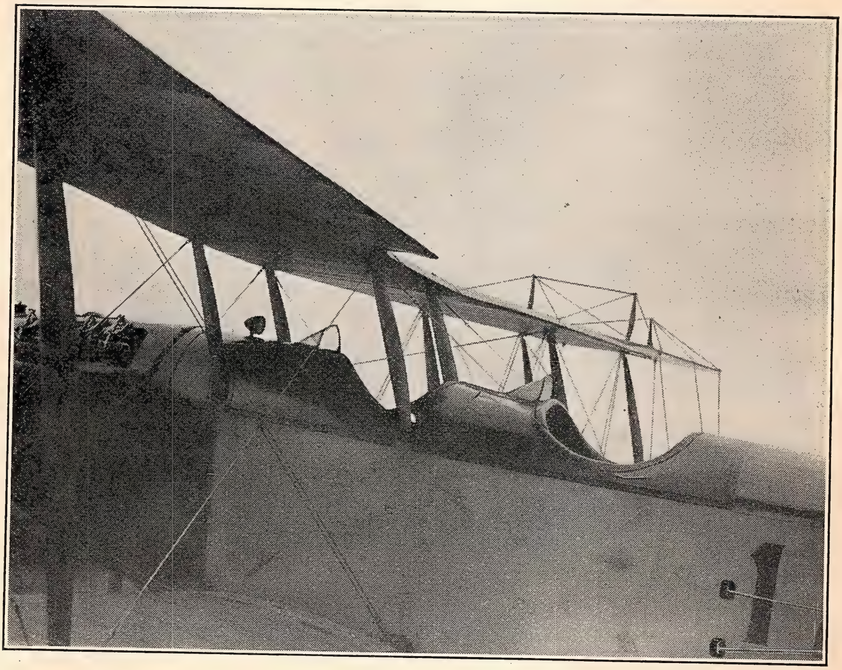


FIG. 15.—Negative ailerons, showing both ailerons set so as to come above the trailing edge of the panel, thus being in a negative position.

HOW TO CHECK DROOP.

The droop is checked by eye, the rigger standing in front of airplane where he can sight along under the panels and see the trailing edge of drooped wing showing below its leading edge, whereas on the other wing these edges will form one straight line to the eye. On the drooped wing he will see below the panel the rear wing outer strut plate, as well as the heads of the nuts securing it, while on the other wing he will see only the heads of the nuts beneath the line of the panel. The disadvantage of this increased angle of incidence which gives the drooped wing more lift, thus overcoming the effect of pro-

peller torque, lies in the fact that when the airplane is gliding to earth with power off the pilot is apt to forget that the drooped wing will be high and the other wing may be smashed in landing. The correct amount of droop to be put in the wing can be determined only by actual flying.

OTHER METHODS OF COUNTERACTING TORQUE.

Another method of counteracting torque is to wash-in one wing half the usual amount of droop and wash-out the other wing the same amount. Still another method is to set one aileron positive or below the trailing edge of panel and the other aileron negative or above the trailing edge of panel. This method reduces the efficiency of the ailerons for lateral control and is not recommended.

GAP.

Gap is the perpendicular distance between the chords of two wing panels and in practice is measured as the perpendicular distance between two straight edges, one held below the upper panel and one below the lower panel, touching their leading and trailing edges, thus corresponding to the wing chords. The gap is usually a little longer than the chord of the wing, so that one panel does not interfere with the air stream passing over the other, while permitting a compact and rigid wing structure.

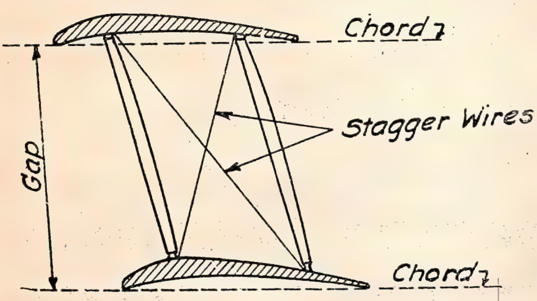


FIG. 16.—Gap.

CAMBER.

Camber refers to the curvature or curved outline given to the surface of an airfoil. It is measured from the chord to the deepest point of the curve, and is given as the ratio of the maximum height of the curve to the length of the chord. Top camber refers to the upper surface of wings and bottom camber to the lower surface of

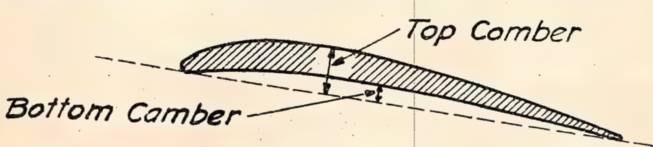


FIG. 17.—Camber.

a wing. The curvature of the lifting surface is extremely important. The purpose for which the airplane is designed, whether for speed or for maximum lift, will determine the wing curve to be used. Naturally to preserve this proper curvature, the wing panel must not be warped or distorted in any way.

SWEEPBACK.

Sweepback or retreat is a term applied to wings whose tips come some distance to the rear of their center point. The amount of this sweepback or retreat is usually given on the specifications as the distance in inches between the wing tip and a line touching the center point of the wings and drawn at right angles to the center line of the fuselage. This line will be the same on each side when airplane is correctly aligned. The purpose of sweepback is to give the airplane lateral stability and it may be used alone or in combination with a certain amount of dihedral angle. It slightly lowers the lifting efficiency of the wings.

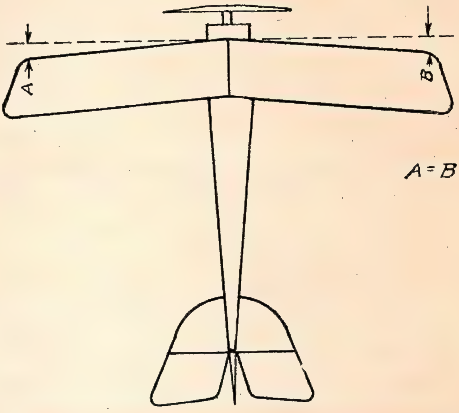


FIG. 18.—Retreat or sweepback of wings.

CHAPTER V.

TRANSPORTATION OF THE AIRPLANE.

TRANSPORTATION OF AIRPLANE BY RAIL.

For shipment, the airplane, with motor installed, should be crated. Blocking should be put under the vertical compression struts and the fuselages evenly supported along its length and securely fastened so it has no play. There must be enough blocking so that no parts will be unsupported, setting up undue bending stresses to break the longerons and allow the engine to fall. The wing panels and smaller parts of the airplane are packed in a separate crate; the panels and airfoils are placed in padded racks so arranged that the panels will not rub against each other nor shift in their places because of the jolting received in transportation. If the fuselage is not crated, it should rest on the landing gear which should be securely cleated to car floor in such a manner that the fuselage will be rigidly braced against shocks from any direction. It is easier to take a little time and care and pack an airplane securely than to replace delicate and expensive parts after they have been broken.

TRANSPORTING CRATED AIRPLANE TO HANGAR.

In lifting a crated airplane into a truck, the end containing the engine must be placed on the truck first. Two 2 by 8 planks placed under the crate will assist later in sliding the crate to the hangar floor if few men are available. An arrow is generally painted on the outside of the crate, indicating the end containing the engine. The engine should not hang over the truck bed without support or the fuselage will be twisted and strained. Rope the crate to the truck bed and with a punch bar, take all slack out of the rope. The object to bear in mind is that there must be no shifting of the load in transit.

Always back into the hangar when unloading. Tip the overhanging end down and slide crate down on timbers which are already under crate by slowly pulling truck out from under load. If men

are available, tip end of crate to floor slowly, move truck out and have men lift crate to floor.

HOW TO HANDLE UNCRATED AIRPLANE.

If the airplane is uncrated and the journey by truck is a short one, load the fuselage onto the truck from a platform, first preparing on the truck floor a bed of three four by fours, projecting out over the end of the truck for a distance of a foot beyond the end of the fuselage. Bolt these four by fours to the bed of the truck.

Now wheel the fuselage on the truck, leaving the tail projecting over the rear end. Brace flat slanting pieces of wood across the four by fours so they will come flush against the tail and prevent the

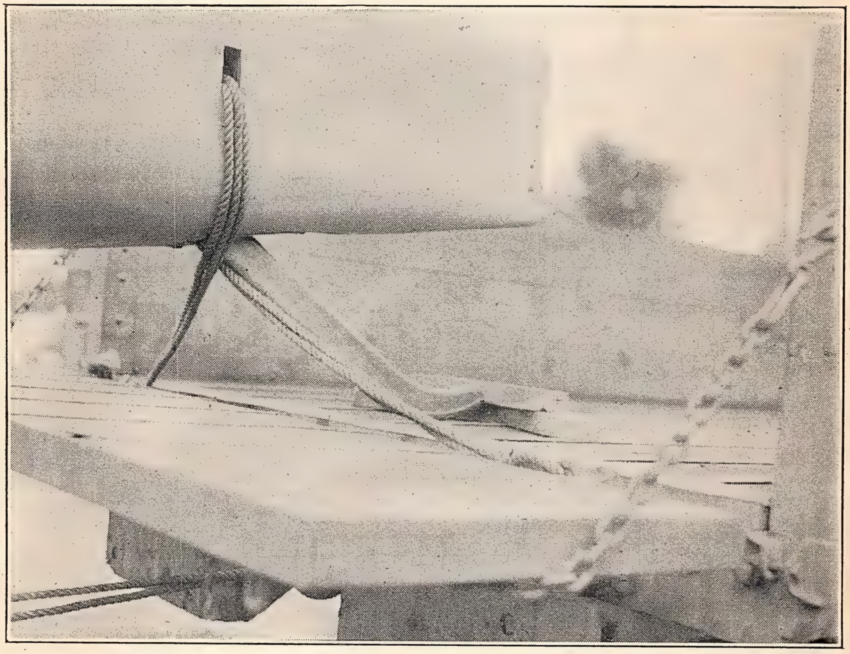


FIG. 19.—Tail of fuselage roped to truck

fuselage from shifting backward. Now block the wheels of the landing gear in front and behind, never permitting tires to rest against the sharp edge of a timber but always against the smooth side of the board so that the tires will not be cut. Nail wooden braces to the truck sides in such a way that wooden blocks will come just over the wheel hubs and prevent the wheels from jolting up and down.

Rope the fuselage to the floor, being sure to cover the engine and fuselage with waterproof covers. In the front corner of the truck

body place the steel drum of gasoline for the airplane. Stand the elevators and rudder on their leading edges on truck floor at the rear end, wiring them by fittings to nails driven in the floor. Secure the ailerons in the same way if disassembled from panels.

To the floor of another motor truck, bolt two four by fours extending out over the rear end at least a foot beyond the tips of the wing panels resting in the truck. Construct padded racks to take four wing panels resting these panels upon their leading edges in these racks on the floor of the truck, the two lower panels in the center. Bolt a 2 by 6 inch timber to the middle of each side of the truck,

FIG. 20.—Fuselage ready for trailing.

perpendicular to the floor extending up above the panels. Run a padded rack across between these timbers into which can be set the trailing edges of the panels. Brace these timbers with stranded steel cable running from their tops forward to the truck body and backward to the ends of the four by fours. Across the ends of the four by fours nail smooth boards, padded, bringing them up against the end of panels to prevent the panels from shifting in the racks.

Now rope the panels to the truck body with ropes passing through the fittings, and cover them with waterproofed cloth if there is danger of rain. See that every nut, bolt, clevis pin, and loose part is securely wired in place before starting the trip so that they can not possibly come loose and be lost. Drive the truck slowly over

rough roads always bearing in mind the fact that the engine is heavy and the load apt to turn over.

UNCRATING FUSELAGE AND WINGS.

When uncrating fuselage, see that the crate rests on smooth, level surface, evenly supported at all points. Let it down on two heavy timbers, instead of on the ground. Now unscrew top and sides after first giving outside a careful inspection to ascertain if crate has been damaged in transit. If damaged, report the matter to the engineer officer for his inspection before opening crate. Fold sides of crate carefully down to form a floor upon which mechanic may stand when working. Never pull crate apart roughly and never pry against fuselage. Leave the bottom of crate and floor timber in place until after landing gear is attached. Uncrate wings and set them on their leading edges on suitable pads. They should be placed at side of hangar until fuselage is assembled.

INSPECT AIRPLANE AFTER UNPACKING.

Inspect all parts thoroughly as soon as they are unpacked. Watch particularly for:

1. Torn or scuffed fabric.
2. Bent, broken, cracked, or checked wood parts.
3. Bent, broken, or damaged hinges.
4. Kinked or broken strands of cable.
5. Bent turnbuckle shanks.
6. Bent aileron control pulley housing.
7. Damaged control horns.
8. Damaged struts, wires, turnbuckles, longerons, fuselage.
9. Injured electric-wire terminals.

Check the following carefully:

1. All parts against shipping sheet to see that none are missing.
2. Tools in tool box. Then O. K. shipping sheet.
3. Take special note of Air Service number of engine and airplane.

THREE METHODS OF RAISING FUSELAGE.

The fuselage may be raised for the attachment of the landing gear in either one of three ways: (*a*) With block and tackle, (*b*) resting bodily on horses, (*c*) blocking up under nose and front flying strut. If block and tackle are available, pass line around fuselage under engine rail and raise fuselage high enough to attach landing gear.

The quickest and simplest method of raising fuselage is to put four men on each side of fuselage and have them lift it up, taking hold under bottom longerons at front cockpit. Slip 4 by 6 beam under master strut across two trestles, hanging sandbag to tail.

If few men are available, raise fuselage, putting blocking under radiator bucket and also under front flying strut. Raise and lower tail, alternately building up blocking under front flying strut and nose, respectively, until fuselage is raised high enough so that landing gear can be attached. Be careful to place your blocking so that landing-gear struts will clear it when attaching them. Be sure to have blocking firmly and evenly built up so that fuselage can not slip with resulting damage to the engine.

Now wheel the fuselage on the truck, leaving the tail projecting over the rear end. Brace flat, slanting pieces of wood across the

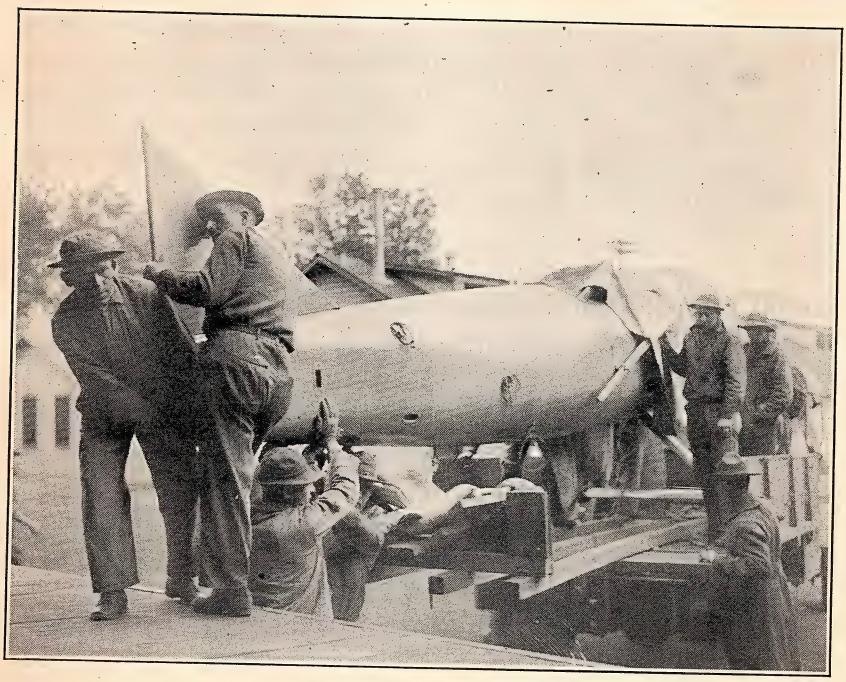
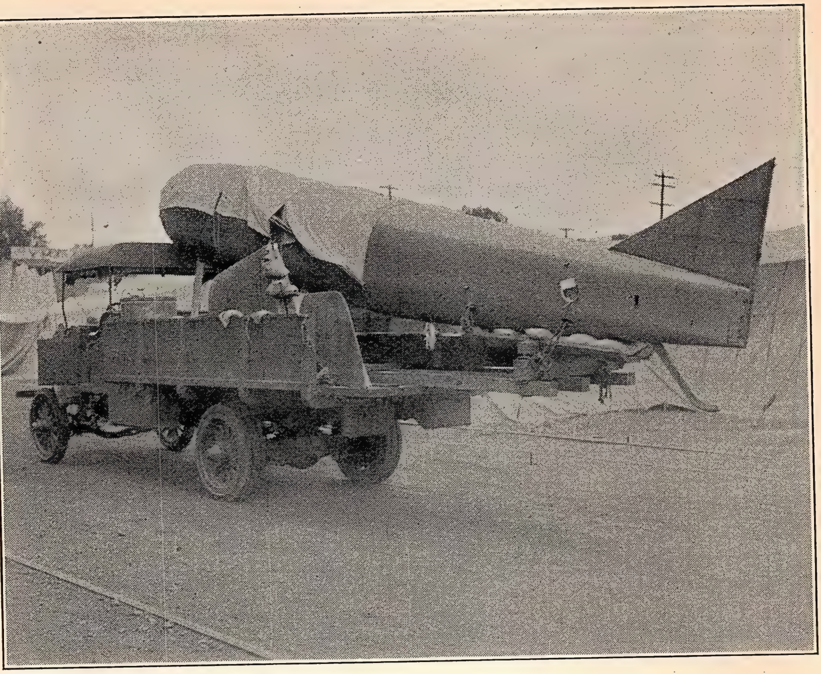
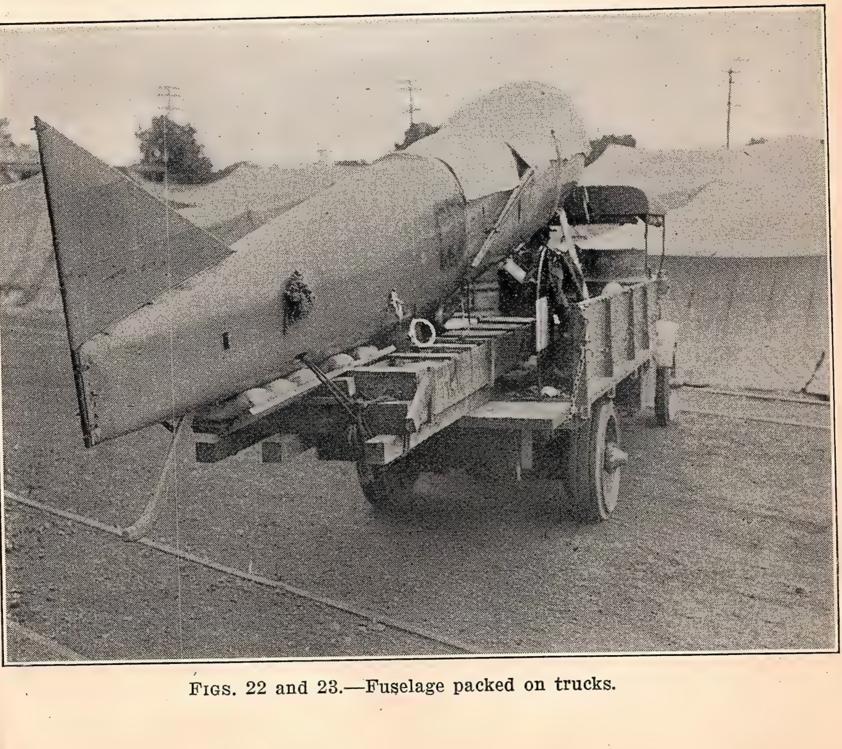


FIG. 21.—Unloading fuselage from truck.

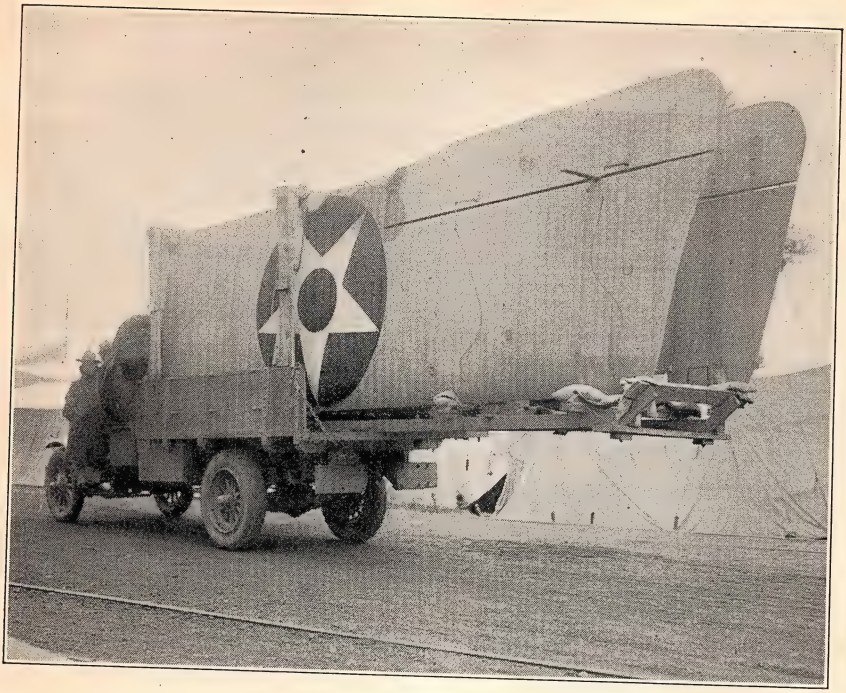
4 by 4's so they will come flush against the tail and prevent the fuselage from shifting backward. Now block the wheels of the landing gear in front and behind, never permitting tires to rest against the sharp edge of a timber, but always against the smooth side of the board, so that the tires will not be cut. Nail wooden braces to the truck sides in such a way that wooden blocks will come just over the wheel hubs and prevent the wheels from jolting up and down.

Rope the fuselage to the floor, being sure to cover the engine and fuselage with waterproof covers. In the front corner of the truck body place the steel drum of gasoline for the airplane. Stand the elevators and rudder on their leading edges on truck floor at the rear





FIGS. 22 and 23.—Fuselage packed on trucks.



FIGS. 24 and 25.—Wings packed on truck.

end, wiring them by fittings to nails driven in the floor. Secure the ailerons in the same way if disassembled from panels.

To the floor of another motor truck, bolt two 4 by 4's extending out over the rear end at least a foot beyond the tips of the wing panels resting in the truck. Construct padded racks to take four wing panels, resting these panels upon their leading edges in these racks on the floor of the truck, the two lower panels in the center. Bolt a 2 by 6 inch timber to the middle of each side of the truck, perpendicular to the floor, extending up above the panels. Run a padded rack across between these timbers into which can be set the trailing edges of the panels. Brace these timbers with stranded steel cable running from their tops forward to the truck body and backward to the ends of the 4 by 4's. Across the ends of the 4 by 4's

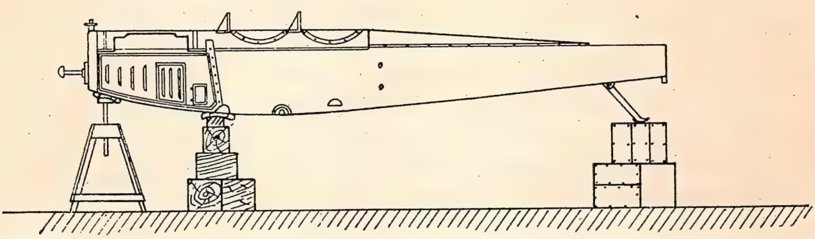


FIG. 26.—Method of raising fuselage.

nail smooth boards, padded, bringing them up against the end of panels to prevent the panels from shifting in the racks.

Now rope the panels to the truck body with ropes passing through the fittings, and cover them with waterproofed cloth if there is a danger of rain. See that every nut, bolt, clevis pin, and loose part is securely wired in place before starting the trip, so that they can not possibly come loose and be lost. Drive the truck slowly over rough roads, always bearing in mind the fact that the engine is heavy and the load apt to turn over.

UNCRATING FUSELAGE AND WINGS.

When uncrating fuselage, see that the crate rests on smooth level surface, evenly supported at all points. Let it down on two heavy timbers instead of on the ground. Now unscrew top and sides, after first giving outside a careful inspection to ascertain if crate has been damaged in transit. If damaged, report the matter to the engineer officer for his inspection before opening crate. Fold sides of crate carefully down to form a floor upon which mechanic may stand when working. Never pull crate apart roughly, and never pry against fuselage. Leave the bottom of crate and floor timber in place until after landing gear is attached. Uncrate wings and set them on their leading edges on suitable pads. They should be placed at side of hangar until fuselage is assembled.

CHAPTER VI.

ASSEMBLY AND ALIGNMENT OF THE AIRPLANE.

CORRECT ORDER OF ASSEMBLY.

1. Unpack fuselage, center section, landing gear, tail unit, and wings.
2. Assemble, place, and align center section.
3. Assemble, attach, and align landing gear.
4. Attach tail unit, checking fin, and horizontal stabilizer.
5. Assemble wing sections, landing, flying and stagger wires brought up enough to hold section in shape.
6. Hang wing sections, loosen flying and stagger wires.

ORDER OF ALIGNMENT.

1. Align fuselage.
2. Take bumps out of wings, bringing up landing wires until threads are covered and sighting leading and trailing edges, including overhang.
3. Put in dihedral angle (string method), checking with diagonals.
4. Tension one front flying wire on each inner bay.
5. Align the chord of wings.
6. Put in correct stagger, airplane being in flying position.
7. Put in droop. Re-check stagger and dihedral angle.
8. Tension all wires correctly and attach drift wires.
9. Align elevators and rudder and adjust controls. Sight stabilizer.
10. Align ailerons and adjust aileron controls.
11. Safety wire all turnbuckles.
12. Oil controls, pulleys, and hinges.
13. Complete inspection of entire airplane.

METHODS OF ASSEMBLY AND ALIGNMENT.

The system of assembly and alignment as developed herewith will apply particularly to the Curtiss JN-4 training machines. They are now given to mechanics as standard practice in assembly and align-

ment. If these methods are thoroughly understood and consistently followed, the mechanic can assemble and align any machine which may be assigned to him.

ALIGNMENT OF THE FUSELAGE.

THE STATIONS OR STRUT NUMBERING.

The fuselage must be stripped completely for truing up. Starting at the front of the fuselage is situated the radiator or nose plate. The nose plate is made of sheet steel on some machines, and is securely bolted to the ends of the four longerons. The vertical struts directly following are numbered and designated as stations No. 1, 2, 3, 4, etc., to the tail post. The struts decrease in length, beginning at station No. 5 (on the Curtiss fuselage), this giving a tapering effect and streamline form to the fuselage. When truing up the fuselage always give the diagonal bracing cables in sections 1, 2, 3, 4, and 5 extra tension to take the extra weight which will be placed there.

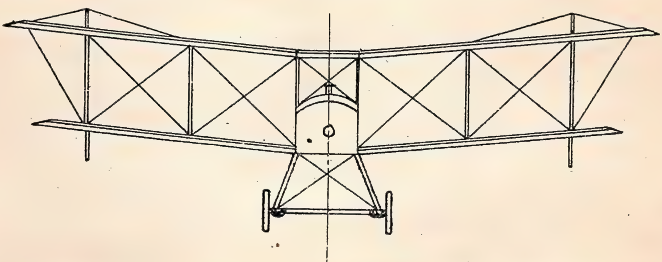


FIG. 27.—Order of alignment.

FUSELAGE ALIGNMENT BY THE STRAIGHTEDGE METHOD.

Before starting see that all turnbuckles have about two threads uncovered, and that the straightedges are true and of the same width. When any station or section is lined up, see that all threads are covered and that the wires are of equal and proper tension.

1. Place horse under master strut and station No. 10. These horses will be called "suspension points."

2. Trammel all stations from master strut to tail strut and lower horizontal sections Nos. 1, 2, 3, and lower horizontal flying section.

3. Place first straightedge on upper longerons at front flying strut (or master strut) and the second straightedge on upper longerons at station No. 10. Get the two straightedges level laterally.

(NOTE.—Line longerons vertically by use of plumb lines.)

4. Place third straightedge in front of rear flying strut and true up both laterally and longitudinally by sighting and getting in line with the other two straightedges. Place third straightedge in front of each station and true up in the same manner to rear suspension point.

5. True up tail post accurately by sighting and bringing it into alignment with plumb lines dropped from upper longerons at station No. 10 and squaring longitudinally with upper longerons by the use of a steel square.

6. Stretch a string from center of nose plate to center of tail post and line up center of upper horizontal struts with it by the use of upper horizontal diagonal wires. Place plumb line at center of upper horizontal struts and line up center of lower horizontal struts with plumb line by use of lower horizontal diagonal wires.

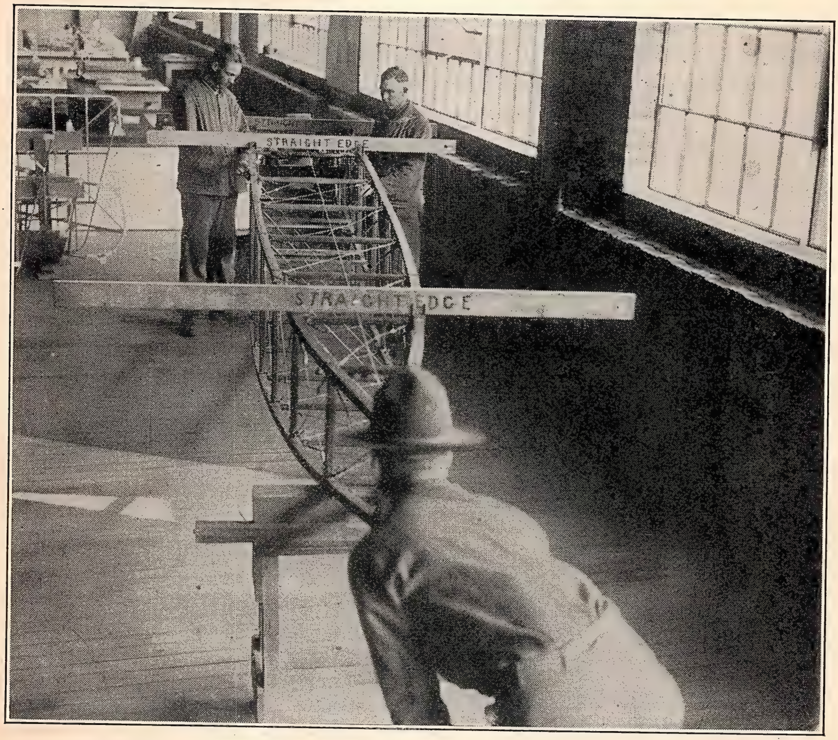


FIG. 28.—Sighting parallel straight edges.

7. Check up engine bed (at this time ship must be level, both longitudinally and laterally) by the use of a level on the engine bed. If engine bed is at an angle, use a protractor level. Adjust side diagonal wires until engine bed has correct angle. Cotter key all parts and lock all turnbuckles with new safety wire.

FUSELAGE ALIGNMENT BY LEVEL METHOD.

Before starting see that all turnbuckles have about two threads uncovered. When any station or section is lined up, see that all threads are covered and wires are at equal and proper tension before

going to next, also that fittings have not slipped or become distorted or wires become strained.

1. Level up suspension points of fuselage laterally and place fuselage on same. (Suspension points are generally at master strut and tail post.)

2. Straighten fuselage fore and aft, approximately, by using longerons at tail and at front flying struts at two points of sight, sighting over tail; then level fuselage longitudinally.

3. Fasten line from center of nose plate to center of tail post, and have plumb lines from center of top horizontal struts.

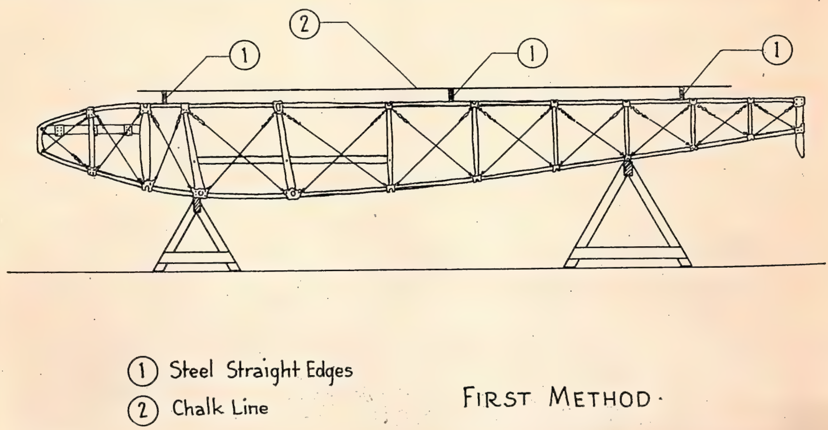


FIG. 29A.—Side view of leveling method of fuselage alignment.

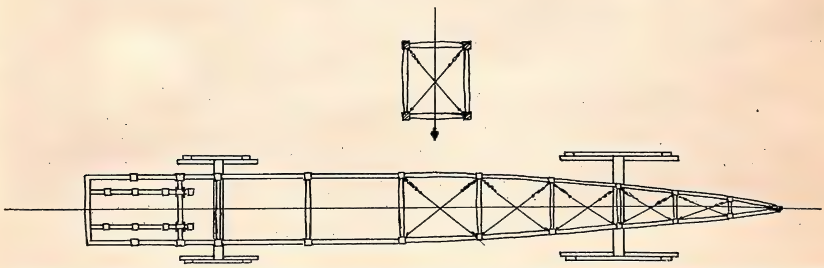


FIG. 29B.—Top view checking struts with string from center of nose plate to tail post.

4. Level longerons at master strut laterally by trammeling master strut station.

5. Level longerons from master strut to rear flying struts, first longitudinally, then laterally at rear flying strut and trammel flying strut station.

6. Trammel lower wing hinge section. (This must be accurate, as wings are fastened here.)

7. Level balancing station both laterally and longitudinally at each station to tail post.

8. Plumb tail post both ways.

9. Bring center top horizontal struts in line with string by top horizontal wires and center bottom horizontal struts in line with each plumb line by lower horizontal wires.

10. Put equal tension in cross-section wires at each station, seeing that plumb lines remain lined up.

11. Level engine bed both ways by side diagonal wires. If staggered engine bed, adjust to proper angle by use of protractor level.

12. Cotter key all parts; see that all nuts and bolts are in correct positions and safety wire with new wire after ship is in true alignment.

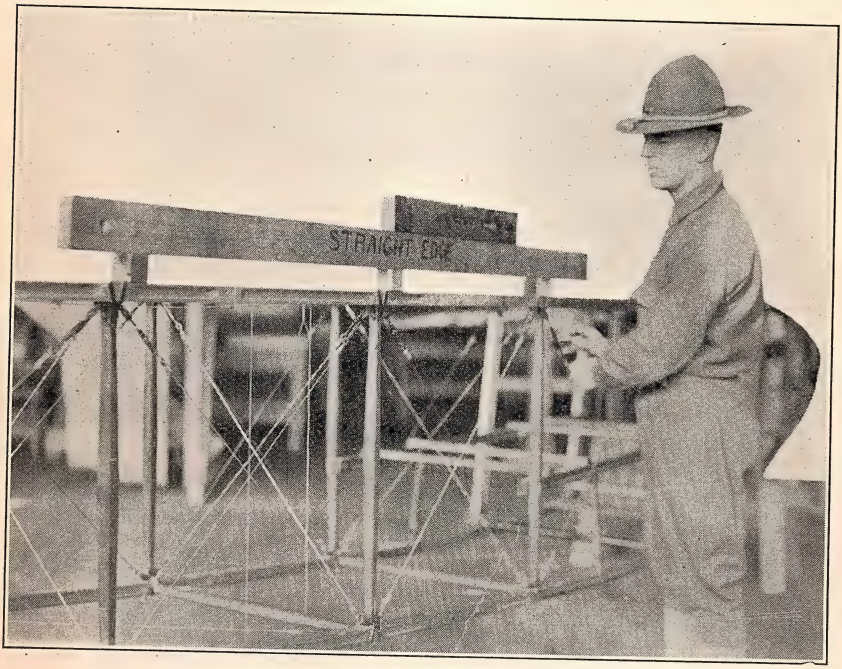


FIG. 30.—Leveling fuselage on longeron.

ALIGNMENT OF FUSELAGE BY TABLE METHOD.

This method of alignment can be used to great advantage in flying schools that have a great number of airplanes of the same design.

1. Construct a table 25 feet in length and 3 feet 6 inches in width. The table top is to be perfectly level and the supports well braced and secured to the floor.

2. Stretch a cord and secure the ends to nails placed in the center of both ends of the table top. This furnishes a center line for the measurements now taken. Transfer full size and very accurately the dimensions of the top side of the fuselage to the table top, the

measurements to be taken from the blue prints provided with each machine.

3. Hardwood blocks are now screwed to the table top, and 1-inch steel square blocks are placed in the center of each section, as shown in the illustration.

4. Slacken all diagonal bracing wires in the fuselage. Now place the fuselage upside down on the table. The longerons will fit in

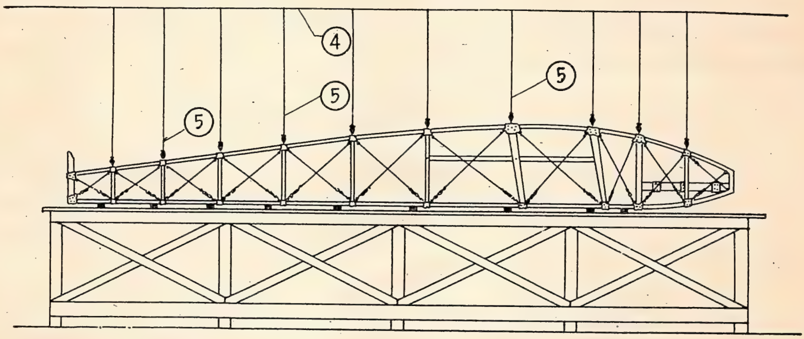


FIG. 31A.—Table method of fuselage alignment.

SECOND METHOD

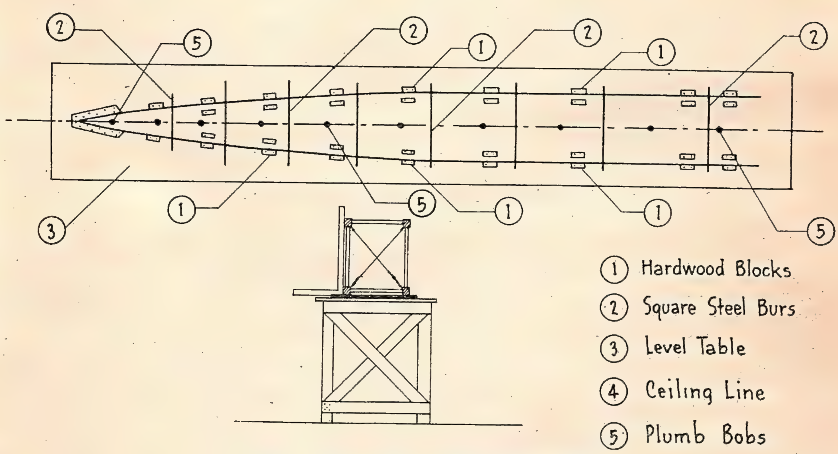


FIG. 31B.—Top view of the table method.

between the hardwood blocks and should touch the steel blocks. Two operations are combined in one by this method of alignment; the straightening of the top longerons and all warp taken out of them. Bring the diagonal bracing wires on both sides of the fuselage and the side that is now held rigid on the table, to equal and correct tension.

5. Now butt a steel square against the struts at each station and adjust the internal diagonal bracing wires until the top struts are

perpendicular to the side struts. Particular attention should be given to the tail post. A final check for tension on all bracing wires should be made, and proving satisfactory, safety all turnbuckles.

PARTS OF THE CENTER SECTION.

The center section consists of two front center-section structs, two rear center-section struts, center-section panel, with two tie wires, attached, two front diagonal cross wires, two front drift wires, and two rear counterdrift wires.

ASSEMBLY OF CENTER SECTION.

Put the struts in strut sockets on panel, being sure they bed well down. Put in top strut bolts from *outside in* for easy inspection. Bring up nuts and cotter. See that tie wires are same length and

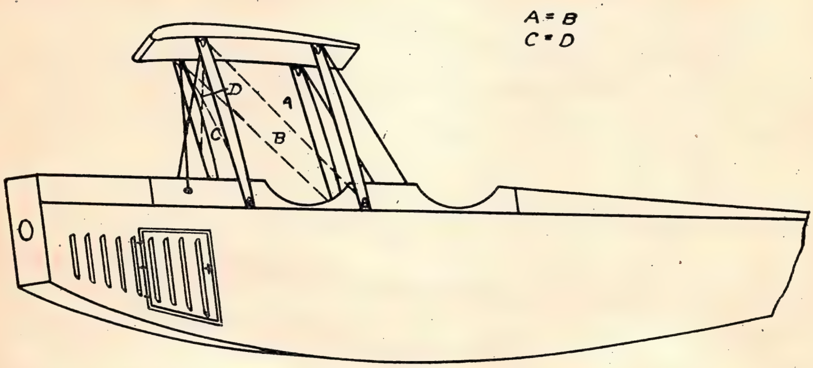


FIG. 32.—Alignment of center section.

their turnbuckles safetied. Notice that front struts are the longest, the panel being set at an angle of incidence on the top longerons, which are level. Now lift center section into place, bedding struts well down into their sockets on top longerons. It is a good plan to check the length of struts before assembling, as the whole alignment will be thrown out if struts are of wrong length. Put in lower-strut bolts from *inside out*, put on nuts and cotter pin. Attach front diagonal bracing wires, front drift wires and rear counterdrift wires, covering threads on diagonal bracing wires and leaving the other turnbuckles loose.

ALIGNMENT OF CENTER SECTION.

The wing sections are hinged to the center section, which forms the fixed point from which to work in aligning the wings. The airplane is designed to fly correctly when the weight, lift, and

other forces acting upon it are equally disposed on each side of a central point which we may consider to be a vertical plane passing through the longitudinal axis or the center line of the fuselage. To obtain this equal distribution of forces acting upon the airplane, the center section must rest squarely upon the longerons both laterally and longitudinally, and must be rigidly secured in that position. Unless the alignment of the center section is absolutely accurate, to better than one thirty-second of an inch in every measurement, the alignment of the whole airplane will be incorrect and it will not fly true.

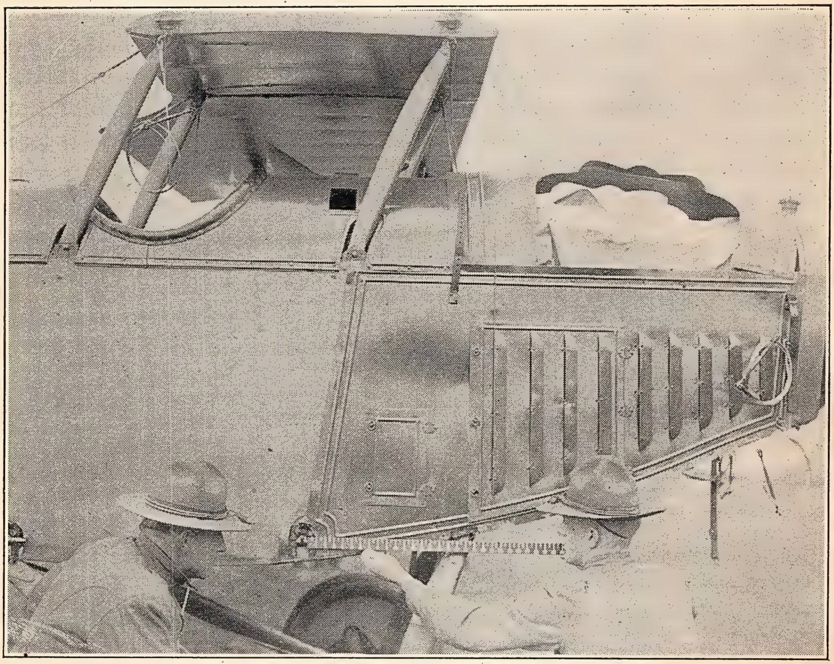


FIG. 33.—Setting stagger at center section.

First measure down from a point on the top strut fitting a certain fixed distance on each front center section strut. Mark this point exactly in the center of the leading edge of the strut. The two diagonal measurements from the top of one strut to the fixed point marked on the other strut will be equal. Adjust the front diagonal brace wires until they are equal. Center section now sets squarely on longerons from side to side.

SETTING STAGGER AT CENTER SECTION.

If it is desired to set stagger before wings are hung, level fuselage into flying position and drop plumb line over front hinge fittings

on each side of center section panel, pulling panel forward or backward with front drift wires or rear counter drift wires until correct stagger measurement is secured on each side between plumb line and lower front hinge fitting. (This is for Curtiss *JN4–B.* With general ordnance airplane, hinge fittings are not set at equal distances back of leading edges of upper and lower panels.) Another way is to hang plumb line over leading edge of center section panel for checking.

CHECKING STAGGER AT CENTER SECTION.

Having set the stagger at center section, make diagonal measurements from center of top bolt in front strut to center of bottom bolt in rear strut, one measurement on each side of center section. These measurements will be equal when the center section rests square and true on the top longerons from side to side at the rear as well as at the front. Adjust with front drift and rear counter drift wires until correct.

HOW TO DETERMINE CORRECT WIRE TENSION.

Safety wire all turnbuckles, being sure that wires are at correct tension, which means tight enough to hold their adjustment against all shocks. Wire tension can best be determined by experience. The experienced mechanic can tell by the "feel" of his wires whether or not they are tensioned properly.

PARTS OF THE LANDING GEAR.

Landing gears differ considerably in construction and design. The essential requirements are strength, lightness of construction, and parts as well streamlined as possible to reduce resistance. The landing gear has streamlined wheels, with wire or metal spokes, on an axle of steel tubing, which is securely held in steel-strut sockets with shock absorber of rubber rope. In strut sockets fit landing-gear struts of spruce, two front and two rear, braced with two front and two rear landing gear diagonal bracing wires of stranded steel cable. The axle rests in bearings of machined brass and is stream lined with a streamline spacer or spreader board of spruce through which generally pass two steel tie rods. These tie rods passing through the strut sockets at each side are fastened with nuts and further strengthen the landing gear. Hub collars of brass are fastened to axle ends with bolts and nuts.

After putting struts in sockets, bringing up nuts evenly and cotter pinning, fasten them together with stream-line spreader. Bring up

nuts on tie rods, slip axle into groove in top of spacer, first putting bearings into sockets, and then turning landing gear bottom side up over two horses, wrap shock absorbers. Start in middle of shock absorber cord which is about 10 feet long and wrap. Pass longer end of rope through hole and inside strut, knotting it temporarily around strut while you wrap the first layer with other half of rope. Bring rope over bottom of strut fitting on the outside, then down and around the brass spool on the inside, back again over bottom of fitting on the outside and so on. The five wraps on each layer will run from the outside in on the bottom of strut fitting and from the inside out on each brass spool when shock absorber is correctly wound. The two ends fasten together over the middle of the wraps, being lashed with strong cord for a distance of about 2 inches with a half hitch at each turn, finally knotting the ends of the cord and covering the wrap with tape and shellac. The most important thing to remember is to have the shock absorbers wound with an even and firm tension, no wraps twisted or crossing each other, and with the idea

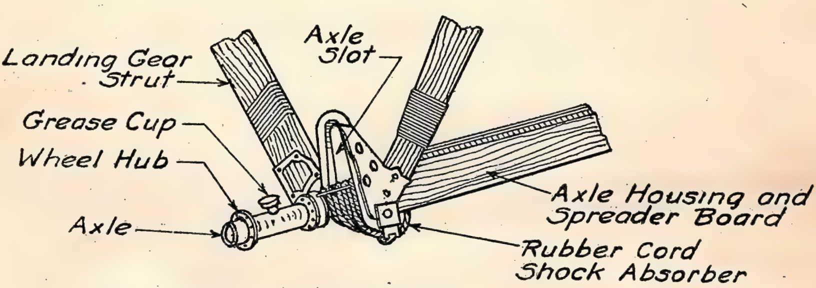


FIG. 34.—Method of winding shock absorber.

clearly in mind that they must be wound tight enough so they will actually take the shock of the landing and yet not so tight that they will break.

Grease axle, clean wheels inside, and slip on. Put on hub caps, bolts from top down through hub caps, put on nuts and cotter pin.

LANDING GEAR ALIGNMENT.

Attach landing gear, put in bolts from top down, bring up evenly, and cotter pin. The landing gear must seat squarely against the fuselage so that the weight of the entire airplane will center exactly on its middle point in landing. The spokes of the wheels must be at an even tension, the wheels themselves well greased, and the tires pumped up to the same pressure so airplane will taxi straight. The bracing wires should be brought up to hold struts exactly in right

position for taking stresses of the landing. There are three methods of aligning the landing gear.

1. From identical point on each upper strut socket measure down fixed distance on each front landing gear strut to a point exactly in center of entering edge of strut. The distance should be the same on each strut. The diagonal measurements from each top fitting to fixed point on opposite strut should be equal. Adjust landing gear diagonal bracing wires until they are equal. In same way make diagonal measurements on rear landing gear struts.

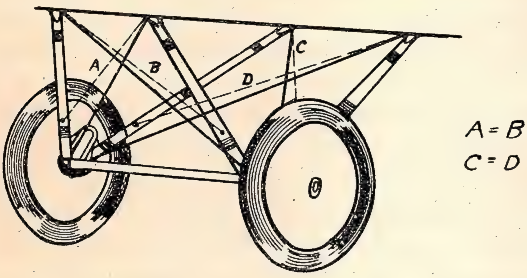


FIG. 35.—Alignment of landing gear.

2. Place level on axle, or if axle is bent, on spreader board, and block up under landing gear struts until axle is level. Place the level next on engine bed bearer or on top longerons at pilot's seat

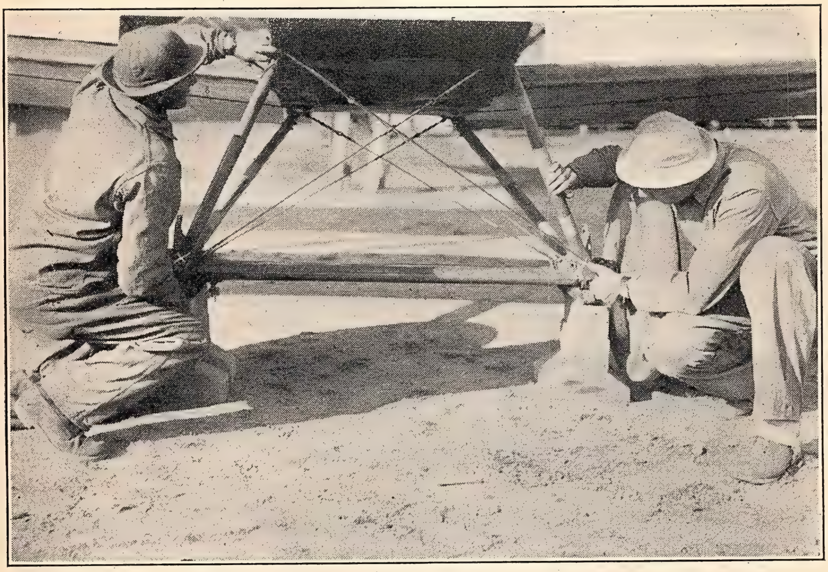


FIG. 36.—Making diagonal measurement.

and adjust front diagonal bracing wires until it is level. Adjust rear bracing wires until diagonal measurements are equal.

3. Drop a plumb line from center point of front horizontal compression strut, removing undercowling, if necessary, to do this. Mark center point of axle with white paint or cloth strip. Drop plumb line from tail post. The two plumb lines and center point of axle (sighting them from front) should be exactly in line if landing gear is aligned correctly.

The first method is the one in common usage. Be sure that all nuts holding landing gear to fuselage are brought up evenly and well cotter-pinned. Diagonal bracing wires must be brought up to strong tension. Safety wire turnbuckles. Pump tires up to 60 pounds' pressure.

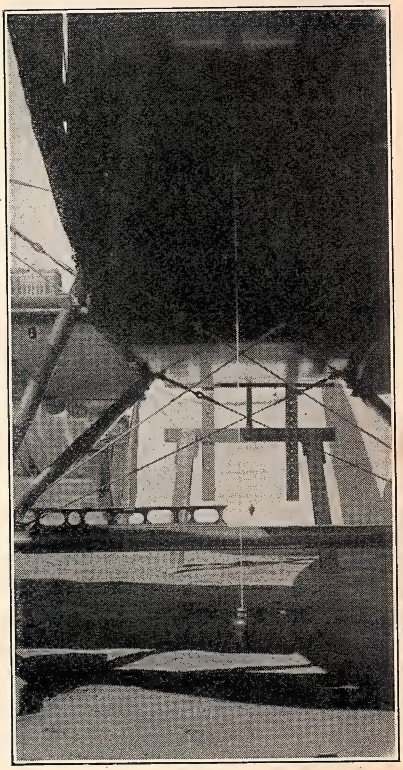


FIG. 37.—Dropping a plumb line from horizontal strut.

ASSEMBLY AND ALIGNMENT OF EMPENNAGE OR TAIL UNIT.

PARTS OF THE TAIL UNIT.

The parts of the tail unit include the horizontal stabilizer, the fin or vertical stabilizer, stabilizer braces of steel tubing streamlined with spruce, elevators, and rudder.

THE HORIZONTAL STABILIZER.

The horizontal stabilizer is a panel, flat on its lower surface and cambered on its upper; designed to give the airplane longitudinal stability. It is fastened flat on the top longerons and is thus set at what is called a longitudinal dihedral angle with the wing panels, these being inclined upward at an angle of incidence. In the Curtiss airplane, the horizontal stabilizer is thus a dead, nonlifting surface. In bombing planes, such as the De Haviland, the horizontal stabilizer frequently has a variable angle of incidence. Its leading edge is hinged to the fuselage and its trailing edge is moved upward and downward by means of a worm gear operating on the tail post and controlled by a cable running from the tail post to the joy stick in the pilot's cockpit. The stabilizer's angle of incidence is increased when the airplane first ascends with its load of bombs and is decreased

when they have been dropped and their additional weight removed. The horizontal stabilizer is braced on its under side with two streamlined braces on each side running to the fuselage.

THE VERTICAL STABILIZER OR FIN.

The fin or vertical stabilizer is a flat panel, generally triangular, set on top of the horizontal stabilizer and at right angles to it. It is designed to give the airplane directional stability. The fin has diagonal bracing wires or rods running from it to the top of the stabilizer.

THE RUDDER.

To the trailing edge of the fin and to the tail post is hinged the rudder, which is used in connection with the ailerons to steer the airplane left or right. It is operated with double-control wires running from a horn on each side of the rudder directly to the ends of a foot rudder bar in the pilot's cockpit. To each of the horns are attached hard-drawn steel bracing wires. They are attached to the trailing edge and must be adjusted with turnbuckles to pull out warps and keep the trailing edge straight.

THE ELEVATORS.

To the trailing edge of the horizontal stabilizer are hinged the elevators or horizontal rudders. They are panels of like size and shape, which are controlled by elevator control wires running from horns on the elevators to a control stick of aluminum tubing, mounted on a trunnion resting on the seat rail in the pilot's cockpit. These elevator-control wires cross each other and are so rigged that their operation corresponds to the natural and instinctive movements of the pilot as he directs the airplane. As he looks upward and pulls the control stick toward him, the elevators are moved upward and the airplane ascends; as he looks downward and pushes the stick forward, the elevators are moved downward and the airplane descends. Bracing wires run to trailing edges from elevator-control horns for pulling out warps and straightening edges.

THE TAIL SKID.

In assembling the airplane, the tail skid is put on immediately after unpacking fuselage and its shock absorber is unwrapped. The nuts must be well tightened and securely cottered, and the shock ab-

sorber wrapped with an even tension at each of its three points of attachment. The metal shoe may be replaced with a new one when worn through. On many modern airplanes, the tail skid is mounted at the end of the tail post in such a way as to turn with the rudder.

ASSEMBLY OF TAIL UNIT.

Place horizontal stabilizer on top longerons, and fasten to them by **U**-bolts secured with nuts and cotter pins. Bring these up firmly. Attach stabilizer braces, put on nuts and cotter pins. Horizontal

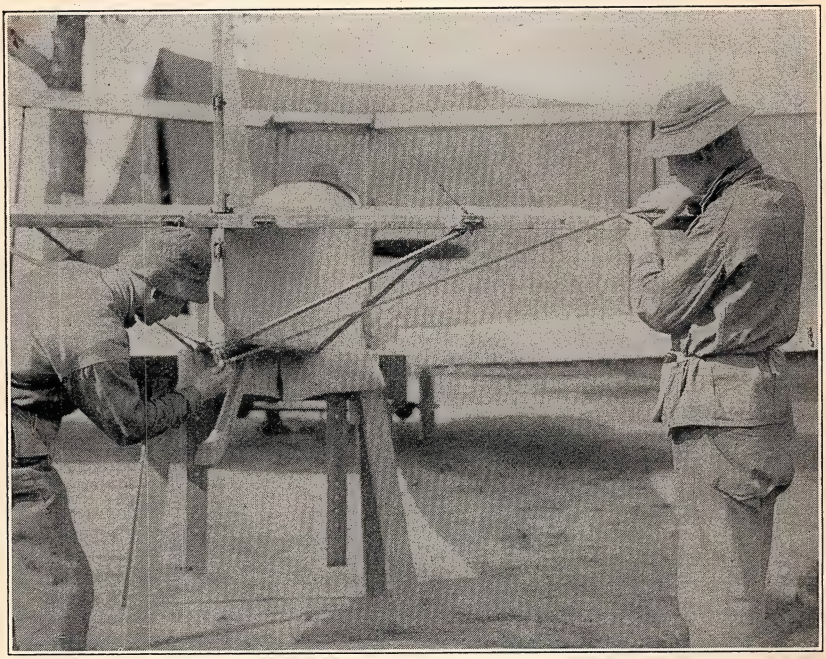


FIG. 38.—Checking alignment of horizontal stabilizer.

stabilizer should be neutral; that is, it should meet the air stream edge on when airplane is in flying position. Bolt on fin but leave bolts loose for easy attachment of rudder.

CHECKING ALIGNMENT OF HORIZONTAL STABILIZER.

Before attaching rudder and elevators check horizontal stabilizer. From center of stabilizer's trailing edge measure out an equal distance on the under surface on each side. Now take diagonal measurements from these points to end of tail post. If stabilizer is square and true, these measurements will be equal. Tighten or loosen braces

until they are equal. If stabilizer is slightly off, shims can be used to bring it up into correct position.

CHECKING ALIGNMENT OF FIN.

Now measure out similar distances from center point of stabilizer's trailing edge on its upper surface. Take diagonal measurements from these points to a fixed point on trailing edge of fin, say, 15 inches up. If fin is perpendicular to stabilizer, these measurements will be equal. Adjust bracing wires of fin until they are equal. A carpenter's square can be used to check fin if same is available.

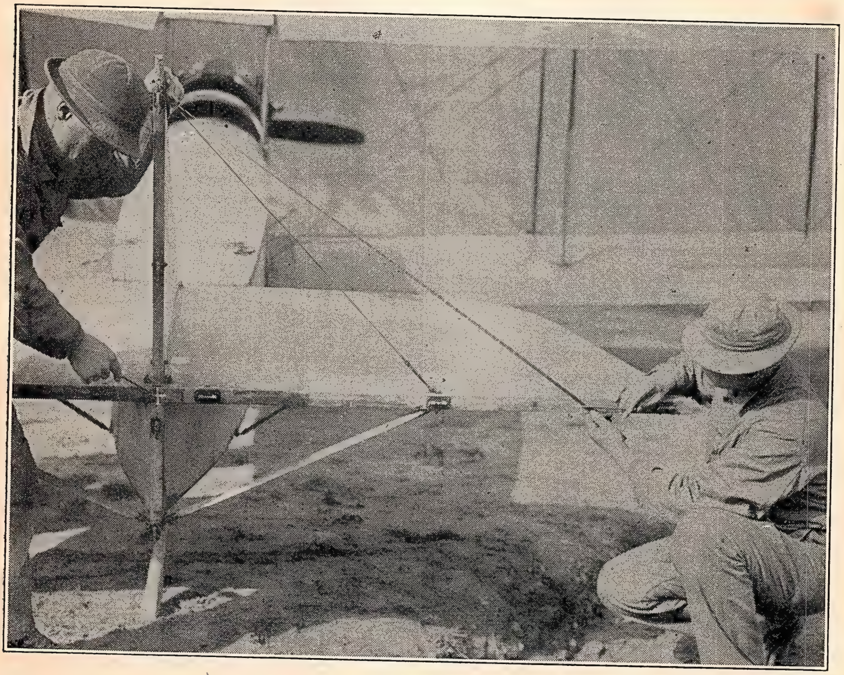


FIG. 39.—Checking alignment of fin.

ATTACHING RUDDER AND ELEVATORS.

Next attach rudder, slipping in middle hinge pin first, all hinge pins going in from the top down. See that trailing edge of rudder is straight and all warps pulled out by means of bracing wires before attaching. Cotter the hinge pins. Attach rudder-control wires to horns, putting in bolts from top down and cotter-pinning nuts. Attach elevators, slipping in middle hinge pin of each elevator first, hinge pins going from outside in. Cotter the hinge pins. See that trailing edges of elevators are straight, with all warps pulled out

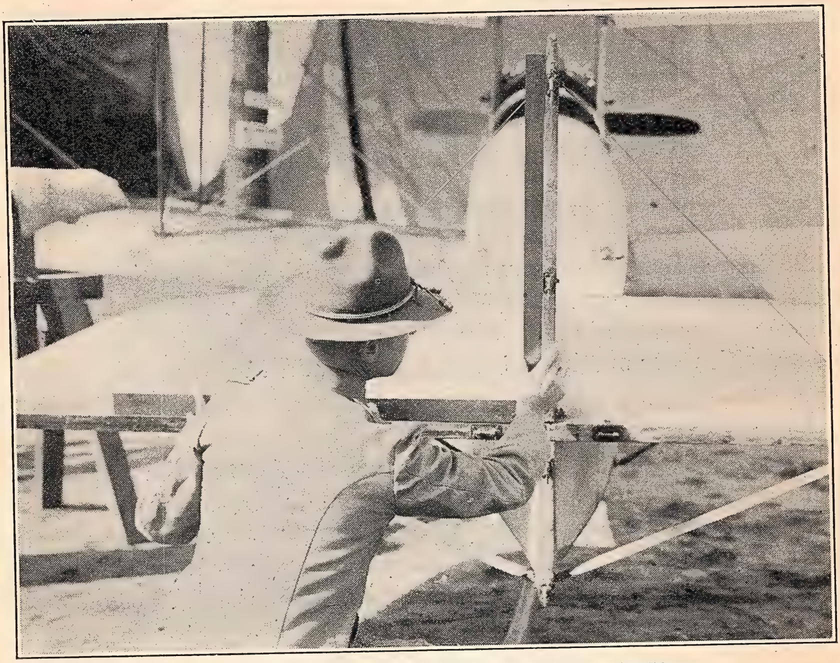


FIG. 40.—Checking the fin and horizontal stabilizer.

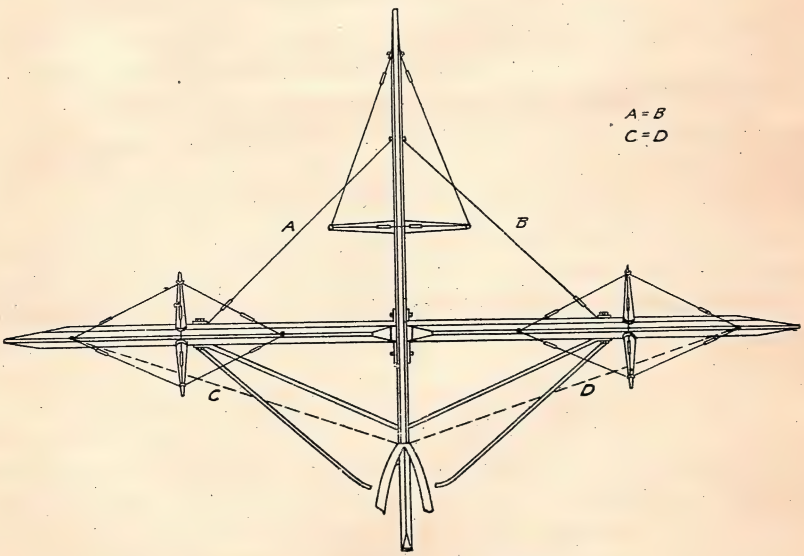


FIG. 41.—Alignment of tail unit.

by use of bracing wires, before attaching elevators. Next attach elevator-control wires, the top ones first, so as to take weight off of elevators and keep trailing edges off the ground. Put bolts from outside in and cotter-pin nuts. Be sure that control wires are attached correctly and that they are not twisted.

ASSEMBLY AND ALIGNMENT OF WINGS.

PARTS OF THE WING SECTION.

A wing section includes upper and lower wing panels with the four connecting wing struts, fittings, etc., the landing, flying, drift, and stagger wires, the ailerons with their control wires, the two cabane struts with their overhang bracing wires, and the wing skid.

WING DIVISIONS.

The wing is divided into three sections, the front section, called the front bay, consisting of the nose form and the nose web of the ribs running from the leading edge back to the main spar.

The second section is called the center bay and consists of the center web, the stringer, and the brace wires. It extends back from the main spar to the rear spar.

The third section is called the rear bay and consists of the rear web of the rib. It extends from the rear spar back to the trailing edge.

HOW "RIGHT" AND "LEFT" WINGS ARE DETERMINED.

When sitting in the pilot's seat, facing forward, the wing on the pilot's right is known as the right wing and the one on his left as the left wing. They are always thus referred to, no matter where the mechanic stands when working around the airplane.

WING PANELS IMPORTANT.

The cambered and linen-covered panels of stream-lined sections are the agents which directly give the airplane its lift. The spruce struts connect and brace the panels, and the whole structure of the section is made strong and rigid by the tensioned wires running between the panels.

LANDING AND FLYING WIRES.

The landing wires support the weight of the wing section when the airplane is on the ground and run from the upper to the lower panels, this being the lowest point of weight of the section. The flying wires run to the upper panels and take the load of the entire airplane when it is in the air, the upper panels forming the lowest point or basis of the load when airplane is flying.

STAGGER, DRIFT, AND ANTIDRIFT WIRES.

The stagger wires hold the panels to the correct stagger adjustment and act as fore-and-aft bracing for the two wings. The wires of a wing are called the internal drift and antidrift wires. The drift wires run diagonally backward and outward from the wing butt to oppose the backward pressure of the wing, while the antidrift wires run forward and outward from the wing butt.

AILERONS.

Set into the trailing edge of the upper panel is a hinged panel called the "aileron," which works simultaneously with the aileron on the other wing to bank the airplane and to help give it lateral control.

OVERHANG.

The cabane struts running up above the outer struts serve, with the overhand bracing wires, as a truss to support the weight of the overhang of upper panel.

WING SKID.

The curved wing skid of rattan or bamboo is fastened to the underside of the lower panel and takes the shock if in any bad landing the wing should strike the ground.

SPARS.

The spars are long pieces of wood running through the wing lengthwise, to which the ribs are attached. The front or leading spar is called the main spar. The other is called the rear spar. They are made of spruce and are always in one solid piece. They are usually lightened by channeling into I-beam form.

KINDS OF RIBS.

There are three kinds of ribs in a Curtiss wing. Each is divided into three sections, the front nose web, the center web, and the rear trailing web. They are called the compression ribs, lightened ribs, and box ribs.

LEADING-EDGE FORM.

The leading-edge form is usually made of spruce. It extends along the leading edge of the wing and the ribs are attached to it.

TRAILING-EDGE FORM.

The trailing-edge form is made of flattened steel tubing or spruce and extends along the trailing edge of the wing.

OUTER AND INNER BAYS.

The cubical space inclosed between the upper and lower panels and the inner and outer struts is known as the outer bay, and the similar space inclosed by the upper and lower panels, the inner struts, and fuselage as the inner bay. Wires and fittings may be conveniently referred to by giving their location at the inner and outer bay and on the right or left wing.

DISTINGUISHING UPPER AND LOWER WINGS.

The upper and lower wings of the plane may be determined by the manner in which the fittings are placed. The lower wing has the strut fittings on the top, while the upper wings have the strut fittings on the bottom.

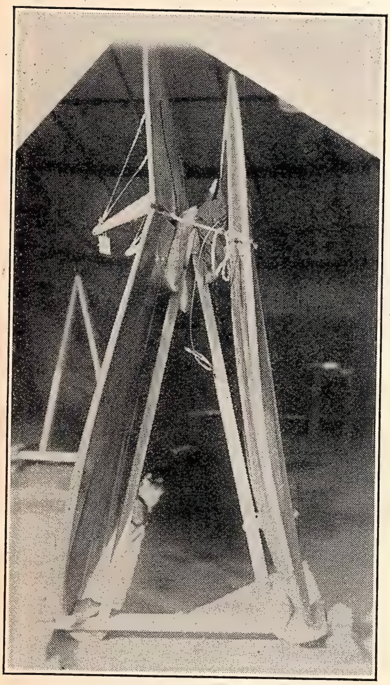


Fig. 42.—Placing of wing panels when airplane is disassembled.

ASSEMBLY OF THE WING SECTIONS.

Place the wing panels on their entering edges, resting on pads to prevent any damage to the entering edge. Connect the stagger wires loosely. In assembling wing sections always put in clevis pins from the top down. When the airplane is in flying position they then remain in position even though cotter pins should come out. Always start turnbuckles evenly, showing same number of threads at each end.

RIGHT METHOD OF PLACING STRUTS.

Now put in the struts, placing bolts from outside in so that pilot can see all nuts. Cotter-pin nuts. If struts are of unequal length, long struts will be placed on the inside next the fuselage, the lighter ones on the outside. If struts taper more toward one end than the other, the end with the long taper is the top end. Struts are also numbered as follows:

The struts on the Curtiss are numbered from left to right across the leading edge from 1 to 4, and across the trailing edge from 5 to 8. When numbers are painted on struts they are so placed that when struts are placed correctly the numbers will all be visible from pilot's

seat, right side up, on the inside of the struts toward the bottom. Should the airplane have a fixed dihedral angle in the lower wing panel, the outer struts will be shorter than the inner ones.

METHOD OF CONNECTING WING WIRES.

Now connect landing and flying wires but bring up turnbuckles only enough to hold the wing section in shape. Next attach aileron, inserting hinge pins from outside pointing in toward center. Attaching compensating wire to control horn on upper side, putting bolt from outside in. Cotter-pin the nut. See that ailerons trailing edge

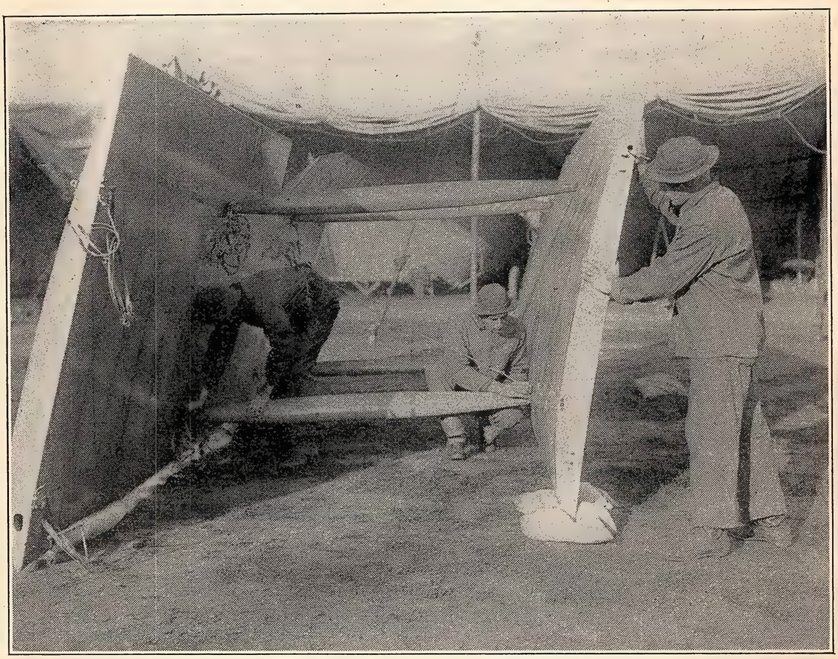


FIG. 43.—Assembly of wing section.

is straight and free from warps, that bracing wires are at correct tension and their turnbuckles safetied. Where airplane has double landing and flying wires rig the flying wires in front of the landing wires, one landing wire coming between the two flying wires and the other landing wire behind flying wire. Single landing wire always goes between two flying wires.

PRELIMINARY INSPECTION OF WING.

Attach wing skid, putting in bolts and cottering nuts. Now look over the wing section carefully to make sure that all clevis pins and

bolts are in correctly and all nuts cottered. Leave overhang bracing wire turnbuckles loose, as overhang is finally adjusted after wing section is hung.

HANGING THE WING SECTIONS.

Now lift the wing section and hang it to the wing hinge fitting, having men support it at the butt of panels and also at the tip, being careful not to take hold of the trailing edge, but using the handholds

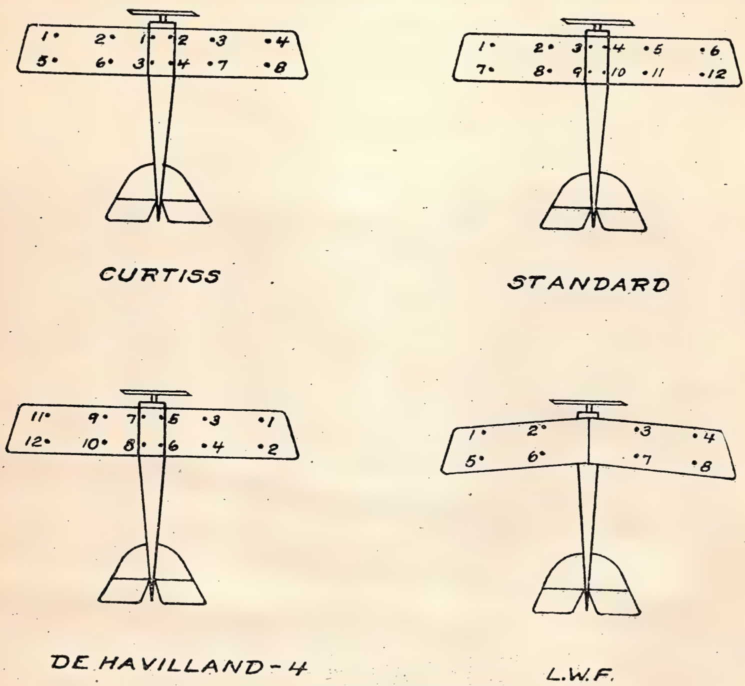


FIG. 44.—Method of placing struts.

and the struts when lifting. Put in the lower pins first, pointing from the front to rear, and insert them so that the holes in hinge pins are vertical to the panels. In this position split pins can be easily inserted. Now insert upper hinge pin, also pointing them front to rear. Next attach inner landing and flying wires. Now place horse under lower panel at outer strut under wing skid fitting, to hold up weight of wing section. Assemble and attach the other wing section in the same order. Cotter pin and safety wire the wing hinge pins. Bring up the landing wires until the threads are just

covered and loosen the flying and stagger wires on both sections until threads are completely uncovered.

AILERON CONTROL AND COMPENSATING WIRES.

Connect compensating wire on the top of upper panel, cotter pinning the nut on bolt. Connect aileron control wires where they pass into fuselage at butts of lower panels.

FIG. 45.—Lifting a wing section.

CHECK THE STRUTS AND FITTINGS.

It is well to check the length of struts to be sure they are correct before assembling wing sections and also to check the position of fittings on the panels, making sure that corresponding fittings on each panel are at the same distance from butts.

SIGHTING EDGES OF WING PANELS.

Go to the tip of the wing and sight along the entering edge first and then the trailing edge, taking out any bumps with the landing wires. Then sight spars to see if they are straight. Such bumps simply indicate that the panel is supported by wires that are unevenly tensioned. Sight both the upper and lower panels, from a

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point opposite the outer strut, as this is the last fixed point of support for the panel, and if bumps are found at the wing tip beyond this point, they can not be pulled out with landing wires. Get these edges straight.

PLACING DIHEDRAL ANGLE IN WINGS.

If the landing wires have been evenly brought up until the threads are covered, the wings should be inclined upward at nearly the correct dihedral angle. Measure out a fixed distance from the butt of each upper panel; say, for instance, 13 feet 6 inches on the Curtiss,

FIG. 46.—Sighting edges of wing panels.

which will give a point opposite the outer strut fitting. Mark this point with a small tack driven in the center of the leading edge of the panel. Now stretch a strong cord from one tack to the other, tying one end, and attaching a weight to the other so as to pull it taut. Calculate the rise in inches for the dihedral angle of the required number of degrees, according to the method already outlined. Measure up from the center of the center section panel's leading edge to the cord. This measurement should be the required rise in inches. If the measurement on one side of the panel is short, it means that the wing on that side is low. Pull it up with the landing wires, bringing up each one an equal number of turns so as to keep your wing panel

straight. If the measurement is too great, the wing is high. Let out the landing wires on the high wing.

CHECKING DIHEDRAL ANGLE.

Now check this rise in inches when you have the correct measurement at each side of the center section panel, by taking diagonal measurements from the center point of the center section panel's leading edge to a point on each lower panel opposite the outer strut fitting. This measurement should be the same on each wing if the dihedral angle is correct. It is a good plan to have the dihedral

Fig. 47.—Measurement of dihedral angle.

measurement a little "strong" to allow for the downward pull of the flying wires when they are tensioned. Check this diagonal measurement after tightening one flying wire on each wing.

ALIGNING CHORD.

Next, the airplane being in true flying position, select a point about 10 feet in front of plane where the landing gear diagonal bracing wires, as you sight across them, form one "X" to the eyes. Then sight along the lower panels from side to side underneath. As you

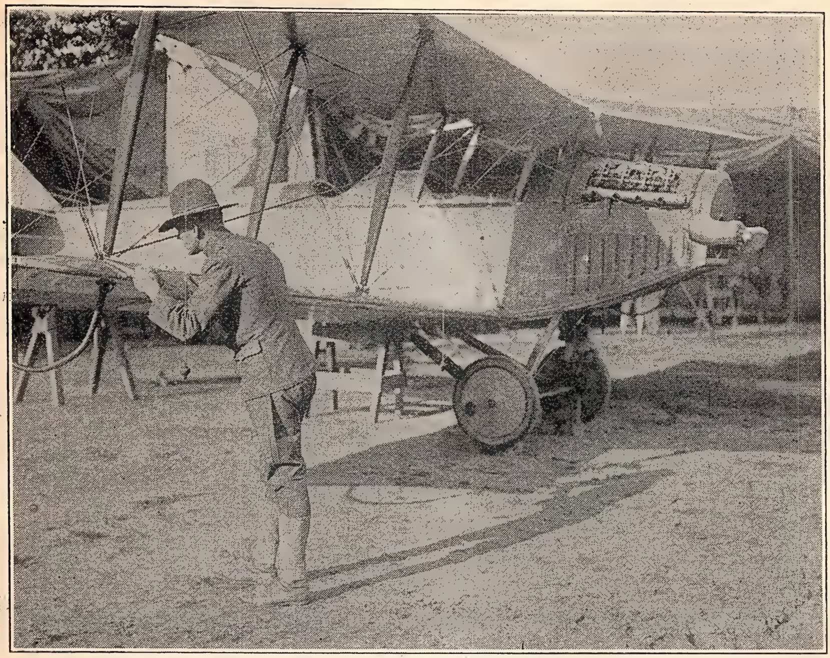

Fig. 48.—Checking dihedral angle.

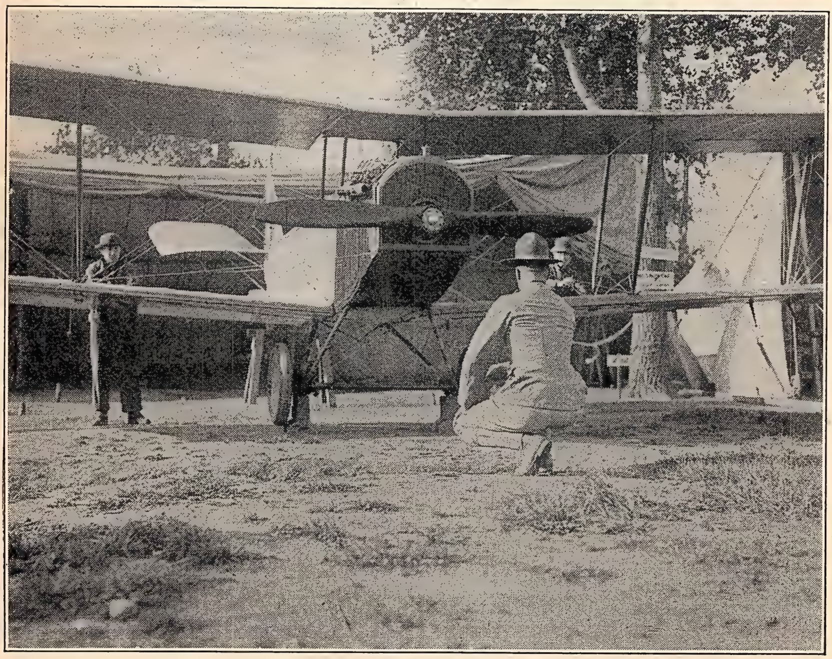

Fig. 49.—Alignment of chord.

slowly raise your head, when the wing chord has been properly aligned, the leading and trailing edge of the lower panel should form one straight line to your eyes and no part of the trailing edge should show below this straight line, except perhaps the extreme outer tip of the wing. Pull up the trailing edge or lower it by means of the rear landing wires while the chord is in perfect alignment, first sighting it from wing tips to see that it is not warped.

This is one of the most important steps in the alignment of the airplane. An experienced rigger always takes plenty of time to see that both wings are in perfect alignment as regards the chord, and that both wings are at the same height and inclination as can be deter-

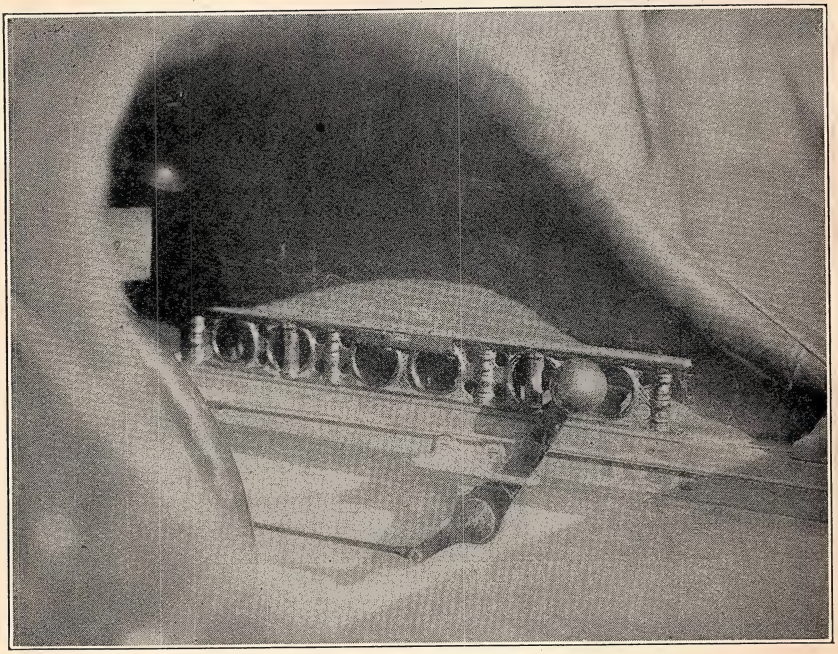

FIG. 50.—True flying position of plane.

mined by the eye. As previously explained, if the trailing edge is warped or bent, the chord must be aligned by sighting the fittings on the under side of the panel, picking out an identical point on each fitting (touching it up with paint or shining it up if necessary) so as to sight the alignment easily.

HOW TO CHECK STAGGER.

Now hang six plumb lines over the leading edge of upper panel, three on each wing, one opposite the outer strut, one opposite the inner strut, and the other near the fuselage. Be sure the airplane is

in true flying position. Check the stagger measurement, taking the shortest distance between the plumb line and the leading edge of the lower panel with a rule. Work outward from the fuselage on each wing. If you have set the stagger at the center section when the center section was assembled, the two measurements next to the fuselage should be correct. If not, you will have to pull the center section panel forward or back with the front drift wires or the rear counterdrift wires until the stagger is correct next to the fuselage.

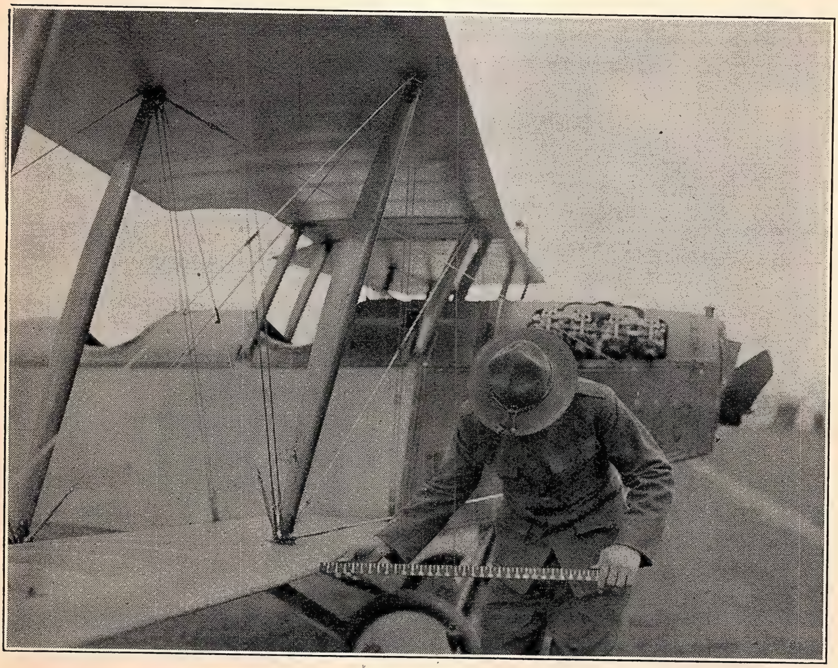

FIG. 51.—Checking the stagger.

Then pull upper panel on each wing forward or back with the stagger wires until every measurement on each wing is correct.

[CAUTION.—In alignment remember that the whole wing section is a structure composed of light wood and metal parts braced with wires, and the increased tension of any one wire instantly affects other wires, increasing or decreasing the tension upon them. So make adjustments with the turnbuckles slowly and carefully. Do not pull wires so tight that wings will be under strain. Having the stagger measurements correct, check the dihedral angle and the chord again.]

DROOP AND THE OVERHANG.

If droop is required, let out the rear landing wires of the drooped wing the required amount so that the trailing edge of this wing is seen below the leading edge when the chord is sighted. Check droop

by sight as previously explained, being careful to put droop or wash-in in the wing gradually and evenly from the butt to the tip. Work from the inner landing wire out. Next align the overhang of each wing, adjusting the overhang bracing wires to get overhang in line with entering edge.

TENSION OF FLYING WIRES.

Now tighten up the flying wires, sighting beams for bows, and checking the dihedral angle and stagger again. See that all wires on the wing are at the correct tension, remembering that they should

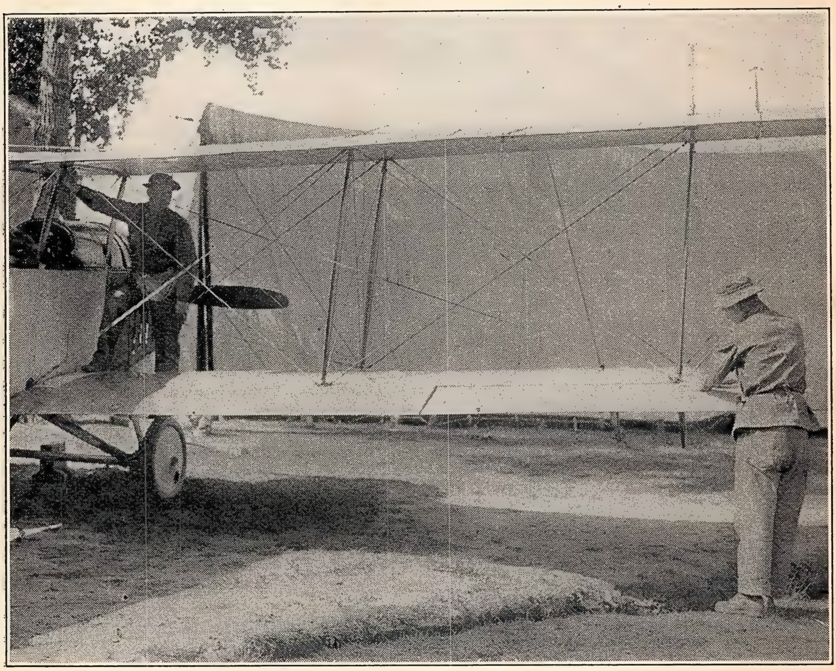

Fig. 52.—Checking the droop.

be tightened enough so they will not vibrate when airplane is flying, but that flying wires are to be left a little looser than leading wires, as the flying wires do not take the load until the airplane ascends. Overhang flying wires may be left a little looser than inner flying wires so they will not pull down the overhang but simply prevent it from collapsing upward.

DRIFT WIRES.

Connect the drift wires and measure their length from front fitting to clevis pin, making sure that they are the same tension. They

should be tight enough to hold the wing sections in their correct alignment and keep them from collapsing backward but should never exert a positive forward pull on them.

ADJUSTMENT OF CONTROLS.

The final step in the assembly and alignment of the airplane is the adjustment of the controls. Get into the pilot's seat and see that the turnbuckles on the rudder, elevator, and aileron control wires are loose. Bring the rudder bar to neutral position, where it is perpendicular to the center line of the fuselage. Block it in this position.

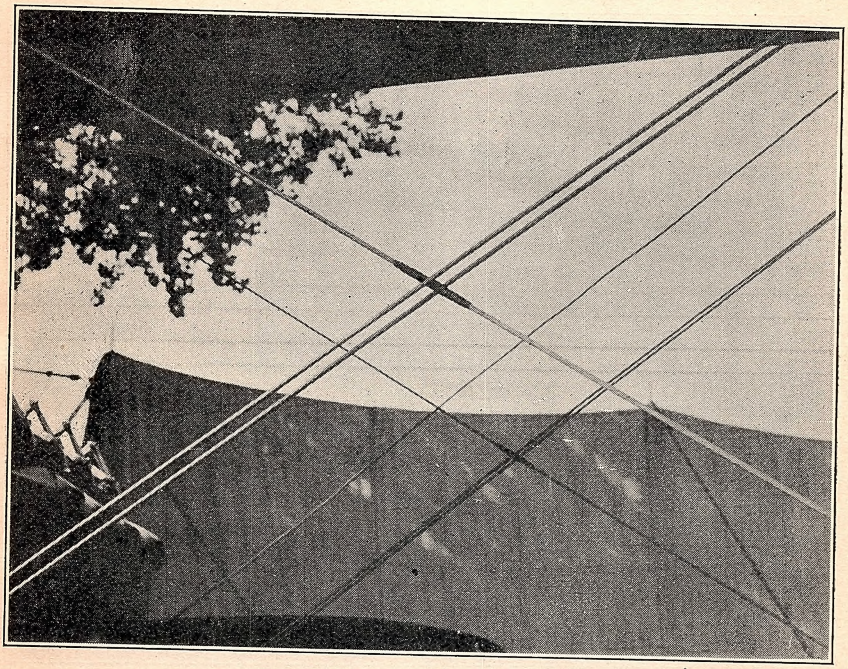

FIG. 53.—Tension of flying wires.

Now you have a fixed point from which to work in adjusting the control wires. Always work from one fixed point to another both in the adjustment and alignment of controls.

HOW TO ADJUST RUDDER CONTROLS.

Send a man back to the rudder and have him hold it so that it is streamlined with the fin, or exactly in line with the center line of fuselage. Tighten one rudder control wire so that it has no slack. Now bring up the other rudder control wire to it, tightening each turnbuckle the same number of turns. Test the adjustment of the rudder, taking out the blocking and moving the rudder left and right. The

slightest movement of the rudder bar should move the rudder; the control wires should have no perceptible play and yet not be so tight that there will be any strain on them. Now have a man get into the cockpit and put his feet upon the rudder bar, keeping his face to the front. See if the rudder exactly streamlines with the fin, and make sure the trailing edge is straight. Finally, safety wire the turnbuckles carefully.

HOW TO ADJUST ELEVATOR CONTROLS.

Hold the control stick so that its top is about 9 inches (in the Curtiss) ahead of the vertical position, lashing or blocking it there. In any case this adjustment is made to permit as much upward movement of the elevators as possible without uncovering threads on lower control wire turnbuckles. Now send a man to the tail and have him hold one elevator in neutral position so that it streamlines with the horizontal stabilizer. Bring up the top control wire so that it holds the elevator in this position. In the same way have the other elevator held up so that it streamlines with the stabilizer and its trailing edge forms a straight line with the trailing edge of the other elevator when sighting it from one side. Next adjust the lower control wires so that there is not much slack in them. Finally test the adjustment of the elevator control by removing the blocking and having a man grasp the trailing edge, first of one elevator and then of the other, moving it up and down so as to be sure that there is no more play on one than on the other. The adjustment should be such that a slight movement of the stick backward will bring up both elevators at the same instant. The movement must be easy and yet there should be no perceptible play in the control wires. Test the trailing edges of the elevators with a string, drawing it taut from one elevator to the other and seeing that the trailing edge is in line with it. Now safety wire the turnbuckles. Remember that the top control wire is to take the weight of the elevator and bring it up to neutral position. The bottom control wire is for adjusting the tension on the stick. *Control wires should never be pulled as tight as wires used in the alignment of the airplane*, such as landing and flying wires.

HOW TO ADJUST AILERON CONTROLS.

The ailerons are the last controls to be adjusted. Connect the lower aileron control wires on each side to the aileron horns, having the turnbuckles loose. Connect and tighten the turnbuckles on the compensating wire above the upper panel until the trailing edge of each aileron is exactly in line with the trailing edge of the upper panel. Have a man on each wing bring up the aileron control wire

turnbuckles until the tension on each side is the same. The slightest movement of the control stick, from side to side, not more than an eighth of an inch, should now move both ailerons. The compensating wire adjusts the ailerons to their proper position in relation to the upper panel, some pilots desiring to have them streamlined with the panel and others wishing to have them set about half an inch below the trailing edge of the panel. The idea is that the pressure of the air against the panel will lift them about half an inch, so that in flight they will be streamlined with the trailing edge. The lower control wire on each wing is for adjusting the tension of the wire on the stick so that it will grip and not slip, moving both ailerons together easily and yet without perceptible play.

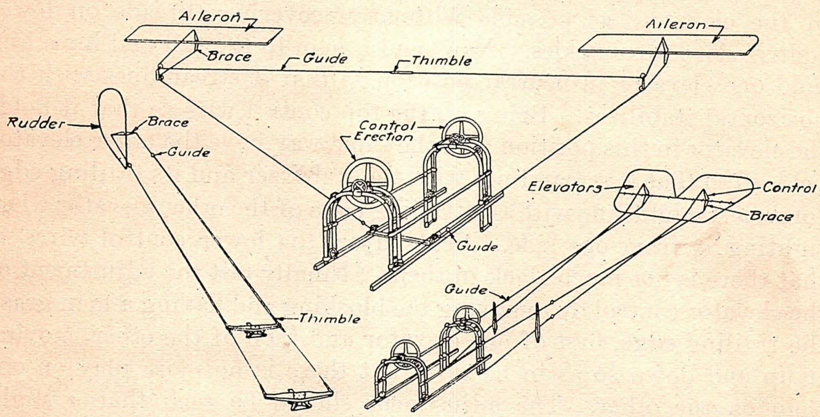

FIG. 54.—Operation of controls.

OIL-CONTROL WIRES.

All control wires should be oiled and greased where they pass through the fuselage or around a pulley. The pulleys themselves should be oiled and watched closely for signs of wear. All movable hinges should be well oiled.

SAFETYING THE AIRPLANE.

After getting the ailerons correctly adjusted, safety wire the turnbuckles. In making adjustments it is necessary to sight trailing edges of ailerons with upper panel and sometimes to true them up again with the bracing wires. Now safety wire turnbuckles on the overhang bracing wires, the drift, landing, flying, and stagger wires.

TAPING THE WIRES.

Tape wires where they cross, tearing electricians tape into strips one-fourth inch wide and taping 1 inch on each side of point where the wires cross, tapering the wrap from the center out and making a neat job of it. Do not tape two wires together.

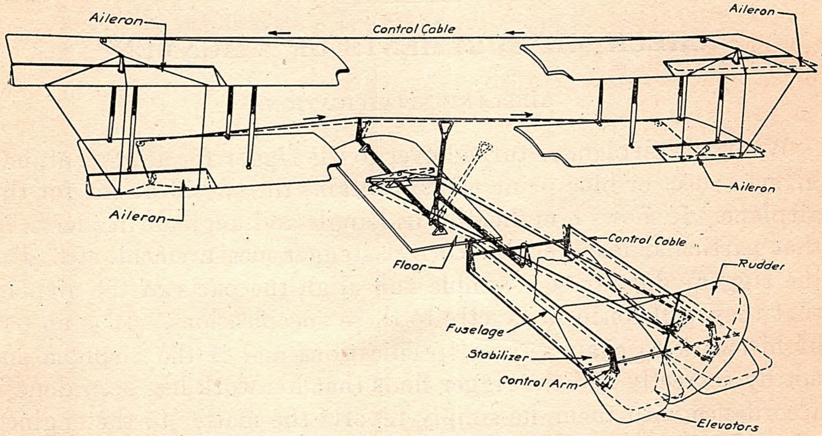

FIG. 55.—Adjustment of controls.

OIL AND GREASE WHEELS.

See that wheels are greased and grease cups full, tires inflated to an equal pressure, and the entire airplane clean and in good shape.